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Office des recherches sur les pêcheries du Canada
Bureau du directeur de la publication
116, rue Lisgar, Ottawa, Canada
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Fisheries Research Board of Canada
Office of the Editor, 116 Lisgar Street
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Adaptive Variation in Swimbladder Length and Volume in Dace, Genus *Rhinichthys*

JOHN H. GEE

Department of Zoology
University of Manitoba, Winnipeg 19, Man.

GEE, J. H. 1972. Adaptive variation in swimbladder length and volume in dace, genus *Rhinichthys*. J. Fish. Res. Bd. Canada 29: 119–127.

Relative growth in length and volume of swimbladder is described in four species of dace, genus *Rhinichthys*. Swimbladder volume varied widely in *R. atratulus*, *R. cataractae*, and *R. osculus* as they adjusted buoyancy by altering swimbladder volume, but variability was less in *R. falcatus* whose range was overlapped by the other three species. A variety of relative growth patterns in swimbladder length was found due mainly to the presence or absence of an inflection which, when present, varied at fork length of occurrence. Where ecological information was known, the length at occurrence of inflection corresponded to a change in environment occupied, from still to current. In the laboratory, *R. atratulus* and *R. cataractae* adjusted swimbladder volume to compensate for different water velocities. All age-groups of the former attained a greater buoyancy than the latter, while *R. cataractae* reached a lower negative buoyancy. Young *R. cataractae* made greater adjustments of swimbladder volume than older fish; the reverse occurred with *R. atratulus*. These adjustments resulted in a significant change in swimbladder length independent of age, except for *R. cataractae* from Lake Winnipeg which had very short swimbladders. The hypothesis that occurrence of the inflection in swimbladder length was caused by the shift from a still to current environment, resulting in a decrease in swimbladder volume and length was accepted for *R. atratulus*, but rejected for *R. cataractae*. An additional hypothesis based on environmental control is proposed.

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L'auteur donne un aperçu de la croissance relative en longueur et en volume de la vessie gazeuse de quatre espèces de goujons du genre *Rhinichthys*. Le volume de la vessie gazeuse varie considérablement chez *R. atratulus*, *R. cataractae* et *R. osculus* parce que ces espèces ajustent leur flottabilité en variant le volume de leur vessie gazeuse. Les variations sont moins fortes chez *R. falcatus* dont le volume de vessie gazeuse chevauche celui des trois autres espèces. L'auteur a détecté plusieurs types de croissance linéaire relative de la vessie gazeuse produits surtout par la présence ou l'absence d'une inflexion qui, lorsque présente, correspond à différentes longueurs à la fourche. Il a de plus constaté, lorsque la nature du milieu ambiant lui était connue, que la longueur à laquelle se produit cette inflexion coïncide avec un changement d'habitat d'eau dormante à eau courante. En laboratoire, *R. atratulus* et *R. cataractae* adaptent

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le volume de leur vessie gazeuse aux variations de vitesse des courants. Toutes les classes d'âge de *R. atratulus* atteignent une plus grande flottabilité que *R. cataractae*, alors que cette espèce-ci réalise une flottabilité négative plus faible que celle-là. Les jeunes *R. cataractae* ajustent le volume de leur vessie gazeuse à un degré plus marqué que les poissons plus âgés; le contraire se produit chez *R. atratulus*. Ces ajustements entraînent des changements appréciables de la longueur de la vessie gazeuse, indépendamment de l'âge, sauf chez les *R. cataractae* du lac Winnipeg, qui ont une vessie gazeuse très courte. L'auteur accepte, pour *R. atratulus*, l'hypothèse que l'inflexion de la longueur de la vessie gazeuse est due à un changement d'habitat d'eau dormante à eau courante. Il la rejette toutefois pour *R. cataractae* et en soumet une nouvelle fondée sur l'influence du milieu ambiant.

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SEVERAL workers have used size of the swimbladder to distinguish between species of dace, genus *Rhinichthys* (Bailey and Allum 1962). The object of this paper is to describe and account for variation in volume and length of the swimbladder of four species to establish the usefulness of these variables as taxonomic characters for this genus.

Longnose dace (*R. cataractae*) exhibit extreme variation (13.9–36.0% of standard length) in length of swimbladder (Bailey and Allum 1962). Longnose and blacknose dace (*R. atratulus*) can alter their buoyancy by adjusting the volume of their swimbladders, becoming more buoyant in still water and less buoyant in current. The change in swimbladder volume made by blacknose at age 2 years resulted in a slight but significant change in swimbladder length (Gee 1968, 1970). The effect of adjustment of swimbladder volume on length by longnose dace is unknown. Furthermore, it is not known if speckled dace (*R. osculus*) or leopard dace (*R. falcatus*) can adjust their buoyancy in this way.

Patterns of relative growth of length and volume of swimbladder of these four species are described and a comparison made to determine whether variation in length is related to volume. Experiments were carried out on longnose and blacknose dace to determine the effect of adjustment of swimbladder volume on swimbladder length of fishes of different ages.

The concept of relative growth has been reviewed by Martin (1949) from which the following terminology is taken: (a) positive heterogony in which a part grows faster than that to which it is compared ($b > 1$) and (b) negative heterogony where a part grows relatively slower ($b < 1$).

Materials and Methods

Swimbladder length (SBL) and volume (SBV) were measured on preserved specimens to provide data on relative growth of these variables. For each species, specimens from populations living in different environments were examined where possible (Table 1). All fish were fixed in 10% formalin and later transferred to 40% isopropyl alcohol. Measurements were made 6 months or more following preservation. SBV was measured by removing the swimbladder, inflating it in a water-filled glass tube (Gee 1968), and recording the volume of water displaced (± 0.005 ml for leopard dace; ± 0.001 ml for remaining species). While the bladder was inflated SBL was measured (± 1.0 mm for leopard dace; ± 0.1 mm for remaining species). Fork length was measured to the nearest millimeter.

Longnose and blacknose dace from Mink River and longnose dace from Lake Winnipeg were tested in the laboratory to determine the effect of adjustment of SBV on SBL. Fish were divided into age-groups on the

TABLE 1. Source, number, and range in size of preserved dace examined.

Species	Drainage system	Area of collection	No. examined	Range in fork length (*mm*)
Leopard dace	Fraser R.	Quesnel to Chilliwack, B.C.	67	23–101
Blacknose dace	Mink R.	Northwest of Sifton, Man.	95	19–80
Longnose dace	Mink R.	Northwest of Sifton, Man.	122	18–86
	Roseau R.	At Roseau River, Man.	93	18–90
	L. Winnipeg	Hecla Is., Man.	114	19–93
	Moose L.	Trout Is., Big Wave Bay, Man.	98	15–94
Speckled dace	Tee L.	Mason Co., Wash.	14	23–49
	Coquille R.	East and North Forks, Oreg.	48	27–81
	Dorsey Reservoir	At outlet, Nev.	23	40–80

basis of length frequency and half of each group was placed in still water aquaria with the other half held in running water aquaria, about 30 cm/sec (Gee 1970). Fish were held under a natural photoperiod at room temperature (22 ± 2 C) and were fed frozen brine shrimp and Tetramin flakes. Age, time of year, and number of dace tested from Mink River were:

Age (months):	3	5	12	17	24	36+
Time of year:	Aug.	Oct.	May	Oct.	May	May
No. in either still or current:	8	16	16	16	16	16

Since little growth occurred between 5–12 months and 17–24 months the results obtained in each of these pairs of age-groups were combined. A similar experiment was completed on longnose dace from Lake Winnipeg with two age groups (24 and 36+ months) taken in August using 16 fish of each age-group in both still and running water.

Dace were held in aquaria for 7 days, as Gee (1968, 1970) has shown that both species adjust their buoyancy in response to a change in water velocity in less than 6 days. They were then removed individually from the aquaria and pithed. Floatation pressure and SBL were measured. Floatation pressure is a measure of buoyancy (Saunders 1953) and was obtained by dividing SBV (milliliters) by weight of the gas-free fish (grams) in water using the procedure given by Gee (1970). Swimbladder length was measured as it lay intact and exposed within the body cavity.

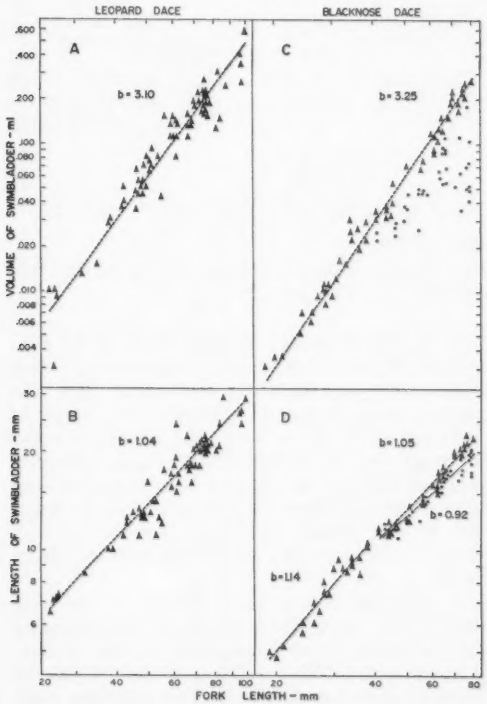

FIG. 1. Relative growth of volume and length of swimbladder in leopard dace (A, B) and blacknose dace (C, D). Regression lines for buoyant fish (triangles) are broken; those for nonbuoyant fish (circles) are solid. Regression lines were not fitted to some data because of extreme variation.

Results

Relative Growth in Length and Volume of Swimbladder

Relative growth of SBL and SBV of leopard dace from Fraser River was linear with positive heterogony (Fig. 1A, B). The swimbladder was well-developed in length and volume. This species is most abundant in still to slow-moving water (< 50 cm/sec, Gee and Northcote 1963).

In blacknose dace from Mink River, SBV was variable amongst fish exceeding 40 mm long. These larger fish were arbitrarily designated as either buoyant or nonbuoyant on the basis of SBV (Fig. 1C). Relative growth of SBV of buoyant fish was linear and showed positive heterogony. Positive heterogony was found for SBL of buoyant fish with an inflection near 40 mm long. Nonbuoyant fish showed negative heterogony in SBL (Fig. 1D). Buoyant fish appeared to have longer swimbladders than nonbuoyant fish. All buoyant fish, except eight, were collected in waters less than 50 cm/sec whereas all nonbuoyant fish, except two, were taken from faster velocities. In Mink River blacknose dace occupy still waters until a length of 35–40 mm after which many move into currents (Gibbons MS 1971).

Longnose dace in Roseau River occupy still water as fry but move into currents exceeding 50 cm/sec when they reach 22–30 mm fork length. Fish captured in still water were designated as buoyant whereas those captured from current were designated as nonbuoyant. For fish less than 30 mm long, the former generally had a larger SBV than the latter, whereas amongst larger fish SBV was variable (Fig. 2A) but smaller than either leopard or blacknose dace of an equivalent size. Relative growth of SBL showed positive heterogony for small buoyant fish followed by an inflection near 30 mm length resulting in negative heterogony for larger fish (Fig. 2B).

In Mink River, longnose dace occupy still waters until about 25 mm long when most move into current (> 50 cm/sec). But unlike Roseau River, areas of current are limited, especially in summer when volume of flow is reduced to about 1 ft^3/sec. Many individuals of all sizes can be found in velocities < 50 cm/sec. SBV was variable and fish were

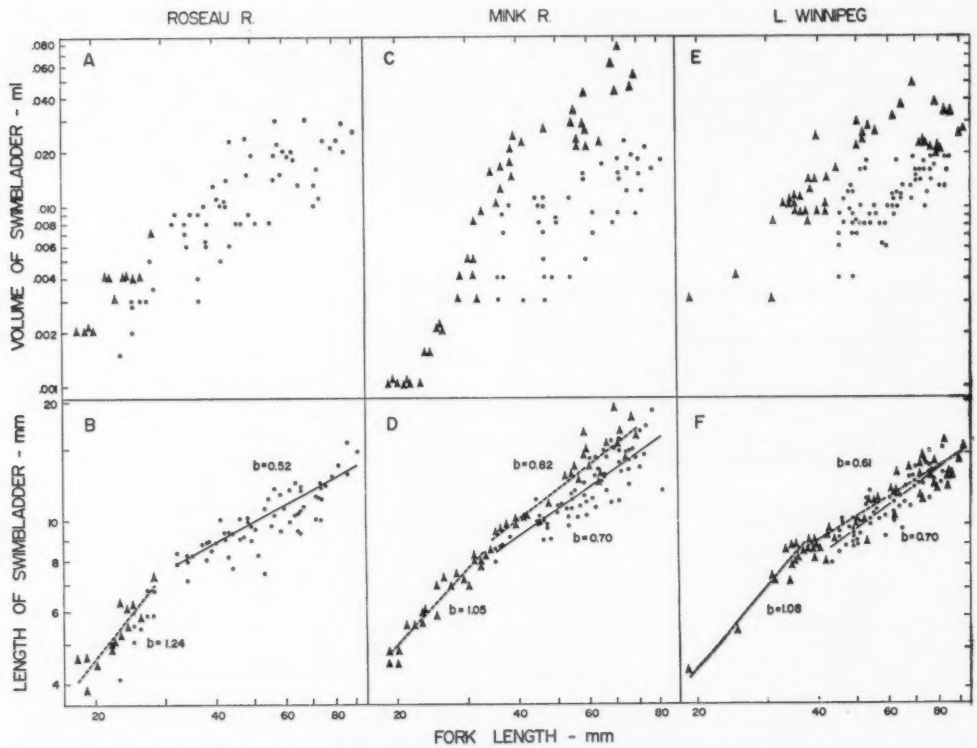

FIG. 2. Relative growth in volume and length of swimbladder of longnose dace from Roseau River (A, B), Mink River (C, D), and Lake Winnipeg (E, F). Symbols and explanation as in Fig. 1.

arbitrarily designated as buoyant or nonbuoyant on the basis of SBV (Fig. 2C). Most of the former were taken from velocities < 50 cm/sec whereas all but six of the latter were taken from faster velocities. Some buoyant fish over 30 mm long had a SBV similar to that of blacknose dace of an equivalent size. SBL showed positive heterogony up to about 33 mm long where an inflection occurred with larger buoyant and nonbuoyant fish showing negative heterogony. Nonbuoyant fish generally have a shorter SBL than buoyant fish (Fig. 2D).

Adult longnose dace in Lake Winnipeg were captured only during July and early August on wave-washed rocky shores of Hecla Island where spawning occurs. Unpublished field observations suggest that fry remain in protected onshore areas until a length of near 30 mm is reached. Then they disperse offshore onto rocky substrates in deep water of strong current, just off Hecla Island. Fish were designated as either buoyant or nonbuoyant on the basis of SBV. All of the former (except two) were captured on calm days whereas 54 of the 67 nonbuoyant fish were captured on windy days when large waves were breaking near shore. SBV was variable (Fig. 2E) and overlapped the range of variation of blacknose dace. SBL showed positive heterogony up to 37 mm long where an inflection occurred followed by negative heterogony for both buoyant and nonbuoyant fish (Fig. 2F). Buoyant fish have a longer SBL than nonbuoyant fish although the difference diminishes with increasing length of fish.

In fish from Moose Lake SBV is variable (Gee 1968) and is generally larger than that described for the above three populations of this species. It varied from 0.030 to 0.290 ml for adults with the majority exceeding 0.060 ml. This variation overlapped that of leopard and blacknose dace. Relative growth of SBL was linear with positive heterogony up to 60 mm length followed by a distinct decrease in SBL (Fig. 3).

Little is known of the ecology of speckled dace. Those from Tee Lake showed a linear relative

growth with positive heterogony in SBV and SBL (Fig. 4A, B). Fish from Coquille River up to 40 mm long had a large SBV and were designated as buoyant. Positive heterogony was evident in SBV and SBL (Fig. 4C, D). Larger fish displayed extreme variation in SBV with the largest possessing a small SBV similar to longnose dace from Lake Winnipeg and Roseau River. A distinct inflection in relative growth of SBL near 40 mm long resulted in negative heterogony for larger fish. Speckled dace from the outlet of Dorsey Reservoir were arbitrarily divided into buoyant or nonbuoyant groups based on SBV (Fig. 4E) with the former having a SBV exceeding the very large SBV of leopard dace whereas the latter had a SBV similar to the very small SBV of longnose dace from Lake Winnipeg and Roseau River. Relative growth of SBL of buoyant fish showed positive heterogony whereas nonbuoyant fish showed negative heterogony with a shorter SBL (Fig. 4F).

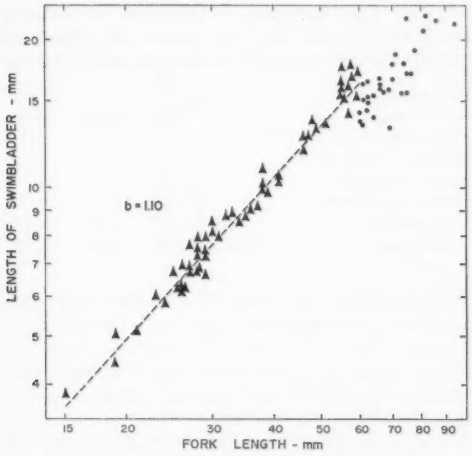

FIG. 3. Relative growth of length of swimbladred of longnose dace from Moose Lake. Symbols and explanation as in Fig. 1.

SBV is highly variable in blacknose, longnose, and speckled dace. Variation within each overlaps the restricted variation found for leopard dace. An obvious relation exists between SBV and SBL and thus overlap exists in SBL amongst the four species (Fig. 5). Slopes of regression lines for buoyant fishes in their initial stanza of growth of SBL and SBL at 28 mm fork length (F.L.) are

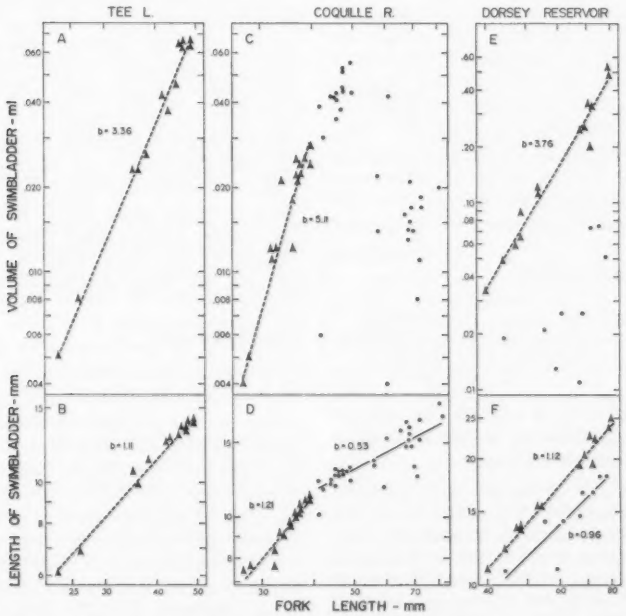

FIG. 4. Relative growth in volume and length of swimbladder of speckled dace from Tee Lake (A, B), Coquille River (C, D), and Dorsey Reservoir (E, F). Symbols and explanation as in Fig. 1.

remarkably similar as shown:

Species	Population	Slope	28 mm (F.L.) SBL	SBL (% F.L.)
Leopard dace	Fraser R.	1.04	7.5	26.8
Blacknose dace	Mink R.	1.14	7.0	25.0
Longnose dace	Mink R.	1.24	7.0	25.0
	Roseau R.	1.05	7.2	25.7
	L. Winnipeg	1.08	6.6	23.6
	Moose L.	1.10	7.1	25.4
Speckled dace	Tee L.	1.11	7.7	27.5
	Coquille R.	1.21	7.4	26.4

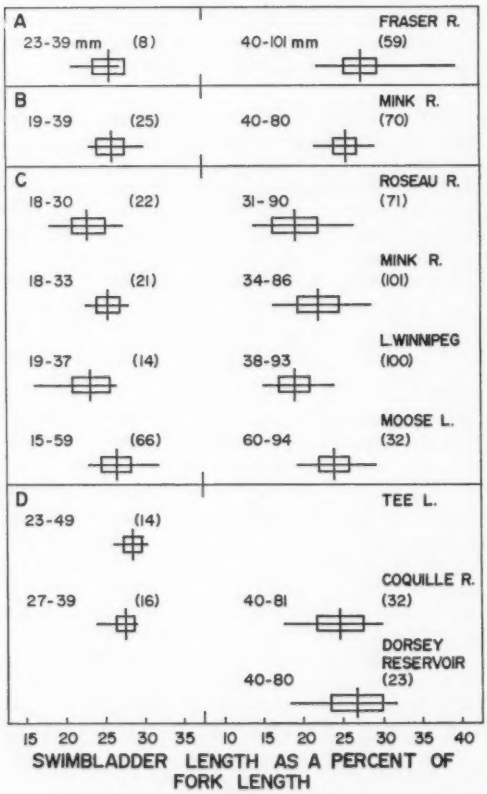

FIG. 5. Variation in SBL of leopard dace (A), blacknose dace (B), longnose dace (C), and speckled dace (D). Populations with an inflection in SBL were each separated into fish in the first and fish in the second stanza of growth of SBL. Leopard dace (A) were arbitrarily divided into two size groups (no inflection present). Vertical lines represent means; horizontal lines, ranges; and open rectangles, one standard deviation on either side of mean. Numbers of fish examined are shown in parentheses.

ADJUSTMENT OF BUOYANCY AND ITS EFFECT ON LENGTH OF SWIMBLADDER OF LONGNOSE AND BLACKNOSE DACE

Longnose and blacknose dace from Mink River adjusted their buoyancy in response to a change in water velocity but the extent of adjustment varied with age (size) of fish and species as follows:

Age (months):	3	5–12	17–24	36+
Mean floatation pressure in still ÷ mean floatation pressure in current:				
Blacknose	1.06	1.45	1.58	2.34
Longnose	2.27	2.20	2.06	1.75

With increasing age, extent of buoyancy adjustment increased for blacknose dace and decreased for longnose dace (Fig. 6A, C). Longnose dace were able to reduce buoyancy lower than blacknose dace, whereas the latter were able to attain a greater buoyancy than the former.

Within each species from Mink River, all age-groups held in still water had a significantly longer swimbladder ($P < 0.005$) than those in current (Fig. 6B, D) independent of age (from analysis of variance).

Longnose dace from Lake Winnipeg also attained a different buoyancy between still and running water, with the smallest age-group making the greatest adjustment. Mean floatation pressure in still divided by mean floatation pressure in current was 2.39 for age 2 years; 1.92 for 3^+ years. The mean floatation pressures reached were lower than for longnose dace from Mink River (Fig. 6C). In Lake Winnipeg specimens SBL was much shorter than in those from Mink River (Fig. 6D), and adjustment of buoyancy resulted in a significant change in SBL only with the smaller age-group ($P < 0.005$, from analysis of variance).

AN HYPOTHESIS

Within some and between all four species, there was a variety of patterns of relative growth in SBL caused by the presence or absence of an inflection. When present the fork length at occurrence was variable and the second stanza of growth was slower relative to fork length than the first. These features of relative growth pattern could be explained by the selection and occupancy of fast water velocities at particular times in the life cycle of populations of some dace which is accompanied by a reduction in SBV resulting in a decreased SBL. The following information supports this hypothesis: (a) leopard dace are found throughout their life cycle in still water, SBV is well-developed,

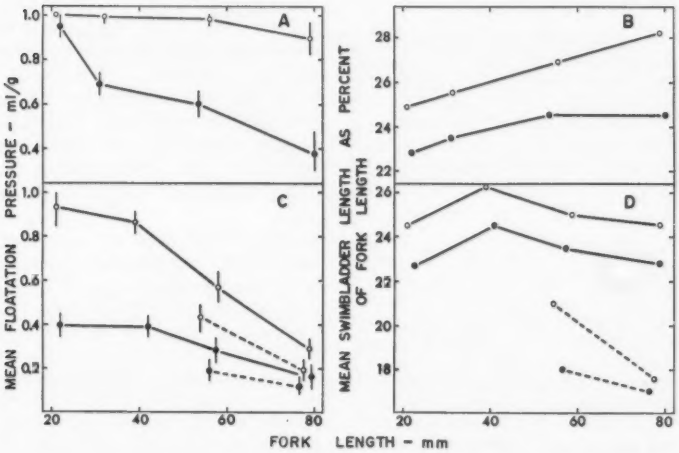

FIG. 6. Mean floatation pressure (ml/g) and mean swimbladder length expressed as a percent of fork length, for blacknose dace (A, B) and longnose dace (C, D). Open and closed circles represent means from fish held for 7 days in still and running water, respectively. Vertical lines indicate one standard deviation above and below the mean. Solid lines, Mink River; broken lines, Lake Winnipeg specimens.

SBL is linear in relative growth with no inflection, (b) stream-dwelling blacknose and longnose fry and longnose fry from Lake Winnipeg occupy still water, SBV is well-developed, and SBL shows linear relative growth, an inflection occurs at a fork length corresponding to that at which these fishes move into water currents, (c) in increased water velocities, longnose and blacknose dace reduce their buoyancy by decreasing SBV, which results in a decrease of SBL.

If variation in pattern of relative growth of SBL can simply be explained by adjustment of SBV then: (a) if the initial stanza of relative growth lines for SBL were projected beyond the length at which inflection occurs, and (b) if fishes exceeding the length of inflection were brought in from the field, held in still water and allowed to reach maximum buoyancy, (c) then one would expect SBL of these fishes to fall on the projected line.

The mean SBL of the various size-groups of longnose and blacknose dace collected from the field and held in still water for seven days described in the above experiment were used to test the hypothesis. Blacknose dace had a mean SBL corresponding very closely to that of the initial stanza of growth and its projection (Fig. 7A). Thus the hypothesis is accepted for this population. But longnose dace from Mink River and Lake Winnipeg did not reach the projected line (Fig. 7B, C). Although mean SBL of the largest two age-groups from Mink River fall within 95% confidence limits to regression estimates, there is still a strong possibility that they fall short of the line. Fish from Lake Winnipeg had a much shorter SBL than those of a comparable size from Mink River, even at maximum buoyancy. Although an increase in SBV resulted in an increase in SBL, it was not sufficient to account completely for the differences between populations of this species and between this species and blacknose dace. The hypothesis is rejected for these populations of longnose dace.

Discussion

There are no species-specific differences in SBL or SBV and neither variable is suitable for distinguishing between any of the four species of *Rhinichthys*.

It is not known if speckled dace can adjust their SBV, and if so what effect it would have on SBL. But inferences can be drawn from the following information. Fish from the outlet of Dorsey Reservoir were 40 mm and longer and fell into two groups; buoyant fish with large SBV and SBL, and nonbuoyant fish with a reduced SBV and SBL. This indicates that fish occupy a range of water velocities from still to fast current. When in current, SBV is reduced, resulting in a reduction of SBL. Those from the Coquille River up to 40 mm long had well-developed SBV, while larger fish

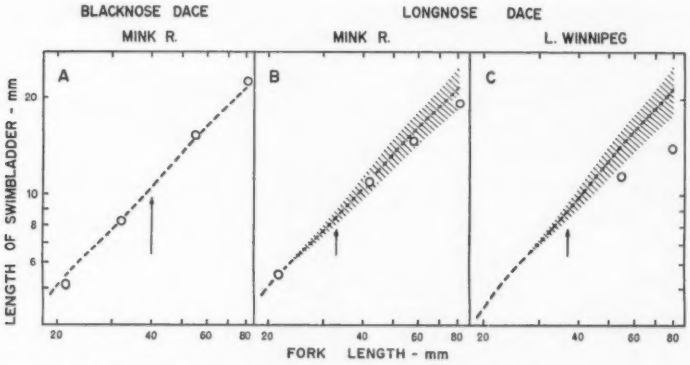

FIG. 7. Comparison of initial stanza of relative growth of SBL from preserved fishes and its projection with mean SBL of fish taken from the field and held for seven days in still water (open circles). Arrows indicate position of inflection, hatched areas represent 95% confidence limits to regression estimates.

showed variation in SBV which was greatly reduced in volume. These fish may occupy still waters until a length of 40 mm is reached, after which water currents are selected. The relative growth in SBL showed an inflection at 40 mm long changing from positive to negative heterogony, a pattern similar to stream-dwelling longnose and blacknose dace. It would appear that much of the variation in SBL of speckled dace is attributed to adjustment of SBV, which in turn is a reflection of the velocity of water in which the fish is living.

There was no indication that leopard dace could adjust their buoyancy.

Nelson (1961) found that those species of Catostomidae which normally occupy fast water currents had a SBL averaging between 13.8–38.8% of standard length whereas those living in still waters averaged between 35–45%. On examination of relative growth of SBL he found no evidence of an inflection, although a closer examination would be warranted as ten of the 19 taxa examined contained five or fewer individuals.

Martin (1949) concluded that differences between populations in slope of a particular stanza were not as frequent as differences in body size at time of inflection. These latter differences occurred amongst populations of longnose and, possibly, speckled dace, and between longnose and blacknose dace. These differences, combined with the lack of an inflection in leopard dace and, possibly, speckled dace from Tee Lake, resulted in considerable variation in SBL within this genus.

In populations of longnose dace from Mink River, Roseau River, and Lake Winnipeg, an inflection occurred in relative growth of SBL between 30–40 mm long, the length at which these fish select fast velocities of water. But longnose dace from Moose Lake showed no such inflection at this size, instead there was a sharp decrease in SBL at 60 mm long. Perhaps these fish live in still water until time of spawning when they move to wave-washed beaches, as do those in Lake Winnipeg. To occupy such an environment would require a reduced SBV resulting in a reduced SBL. The sudden decrease in SBL at 60 mm fork length, the approximate size when sexual maturity is reached, supports this. If this is so, then the hypothesis put forth explains the variation in SBL above and below 60 mm fork length found in this population.

But an alternative hypothesis must be found to explain the presence of the inflection, and reduced relative growth of SBL in the second stanza of populations of longnose dace from Mink River, Roseau River, and Lake Winnipeg. The occurrence of this inflection at a fork length when a marked shift in environment selected is found, argues strongly for an environmentally determined cause, as opposed to a genetically determined one. Such an hypothesis would be that adjustment of SBV, which affects SBL, occurs with a change in current occupied, and that this is combined with a reduced rate of growth of SBL when the swimbladder is in a state of reduced volume. Thus, the swimbladder of fish living in very fast water velocities with a small SBV, would grow at a slower rate relative to fork length than those in moderate currents or still water. This would explain the finding of shorter SBL of longnose dace from Lake Winnipeg when compared to those from more moderate currents of Mink River when individuals of both populations were at maximum buoyancy. In addition, the length of the swimbladder attained

when living in such different environments may, in turn, affect the extent over which SBV may be adjusted as indicated by longnose dace from Lake Winnipeg which adjusted SBV over a lower and narrower range of floatation pressures than those from Mink River. This hypothesis is presently being tested in the laboratory by rearing dace in still and current environments and measuring SBL and their ability to adjust SBV at different times in their lives.

Horn (1970) described an even more striking change in swimbladder morphology. The study showed that a gradual but complete regression occurred in 14 of 15 genera of the suborder Stromateoidei and was related to certain changes in mode of life. He found that pelagic larvae and juveniles had fully-developed swimbladders capable of hydrostatic adjustment. Prior to sexual maturity, these fishes moved to deeper waters, and reabsorbtion of the swimbladder was completed before sexually maturity.

Swimbladder volume and length in three of the four species of *Rhinichthys* was highly variable and overlapped the restricted variation found for leopard dace. It is concluded that in speckled and blacknose dace this variation is due mostly to short-term phenotypic plasticity, in which these fishes adjust SBV in response to a change in water velocity, and that such an adjustment affects SBL. Such plasticity is also common in longnose dace which may, in addition, possess long-term phenotypic plasticity in which the rate of growth of the swimbladder is influenced by the environment occupied. Such a combination of long-term and short-term phenotypic plasticity would be highly adaptive, permitting this species to occupy a variety of lotic and lentic environments in time and space.

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Recovery of Planted Brook Trout, Splake, and Rainbow Trout from Selected Ontario Lakes[1]

J. M. FRASER

Ontario Department of Lands and Forests
Research Branch, Maple, Ont.

FRASER, J. M. 1972. Recovery of planted brook trout, splake, and rainbow trout from selected Ontario lakes. J. Fish. Res. Bd. Canada 29: 129–142.

Recoveries of hatchery-reared brook trout (*Salvelinus fontinalis*), splake (*Salvelinus namaycush* × *S. fontinalis*), and rainbow trout (*Salmo gairdneri*), planted in lakes having different resident fishes, were highest (9–30%) in a lake in which minnows and the brook stickleback were the only other fishes. Recoveries, by angling and gillnetting, were considerably lower (2–15%) in two lakes containing the white sucker and minnows, and still lower (0.5–5%) in two lakes containing spiny-rayed species as well. Recoveries were lowest (<0.5%) in a lake having a complex fish community that included native brook and lake trout. Planted splake and rainbow trout generally yielded higher returns, in weight, than brook trout in comparable situations.

The low survival of planted fish was apparently due to the low fertility of the waters and to competition with, or predation by, resident fish species. Predation by fish-eating birds and mammals may also have had an effect.

The weight of the catch of salmonids exceeded the weight planted in only one lake. Here, the mean yield of planted salmonids was 8.4 kg/ha per year in comparison with 2.6 to <0.5 kg/ha per year in the five other study lakes.

FRASER, J. M. 1972. Recovery of planted brook trout, splake, and rainbow trout from selected Ontario lakes. J. Fish. Res. Bd. Canada 29: 129–142.

Le recouvrement d'ombles de fontaine (*Salvelinus fontinalis*), truites moulac (*Salvelinus namaycush* × *S. fontinalis*) et truites arc-en-ciel (*Salmo gairdneri*) d'élevage, introduits dans des lacs à espèces résidentes différentes, a été maximal (9 à 30%) dans un lac où il n'y avait préalablement que ménés et épinoches à cinq épines. Les "retours au panier" et captures au filet maillant ont été considérablement plus bas (2 à 15%) dans deux lacs contenant des catostomes noirs communs et des ménés, et plus faibles encore (0.5 à 5%) dans deux lacs peuplés d'espèces de poissons à rayons épineux, en plus de catostomes noirs communs et de ménés. Un lac contenant une communauté complexe d'espèces, dont l'omble de fontaine et le touladi indigènes, a fourni le plus bas pourcentage (<0.5) de recaptures. L'ensemencement de truites moulac et arc-en-ciel a généralement donné des captures pondérales supérieures à celui d'ombles de fontaine dans les mêmes conditions.

Le faible taux de survie des poissons ensemencés est apparemment dû à la basse fertilité des eaux et à l'action des espèces résidentes, compétition et prédation. La prédation par les oiseaux et mammifères ichthyophages a pu également avoir une influence.

Le poids des salmonidés capturés n'a excédé celui des sujets introduits que dans un lac. Dans ce lac, le rendement moyen de salmonidés introduits a été de 8.4 kg/ha par année comparativement à moins de 0.5 kg/ha par année dans les cinq autres lacs.

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THIS study assesses the effectiveness of planting hatchery-reared brook trout (*Salvelinus fontinalis*), splake (*Salvelinus namaycush* × *S. fontinalis*), and rainbow trout (*Salmo gairdneri*) in six small Precambrian lakes. Several thousand such lakes in Ontario are planted annually with 1.2 million brook trout and 0.3 million rainbow trout. Approximately 85% of these fish are planted in the spring as yearlings.

The lakes in which the fish are planted vary considerably in morphometry and in physical and chemical characteristics. They also vary widely in fish species composition, and in many lakes

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the species composition has changed. Some lakes, which had few or no other fish when trout were first introduced, now contain various other species such as cyprinids, sticklebacks, suckers, and yellow perch. Stocking has been discontinued in some lakes because the survival of planted trout was obviously low, but in the greater proportion of lakes, where the survival picture has not been established, stocking continues.

The lakes may be placed into four broad categories on the basis of their main species as follows: A (Little Minnow), minnows; B (Crevice, Major), minnows, white sucker; C (Shrew, Billy), minnows, white sucker, yellow perch, pumpkinseed; D (Redrock), minnows, white sucker, yellow perch, pumpkinseed, brook, and lake trout. From 1962 to 1968, six study lakes representing these four categories were planted with approximately 150,000 marked yearlings. The numbers of fish recovered were determined by creel census and by gillnetting.

Methods

Study area — The lakes studied are in, or just outside, the southeast sector of Algonquin Provincial Park near Opeongo Lake (Fig. 1). The park is a 7500 km² tract of land about 200 km north of Lake Ontario in the Precambrian Shield. It is a headwater area, with elevations ranging from 400 to 580 m. The topography is rolling and irregular, with many small deep lakes. Many of these lakes contain brook trout or lake trout (*Salvelinus namaycush*), or both, and have been favorites of anglers since the early part of the century.

The study lakes range from 9 to 302 ha in area, and from 8.5 to 21.3 m in maximum depth (Table 1). All lakes, except Billy Lake, exhibit a sharp thermal stratification by midsummer. Surface waters may reach 24 C during stratification, but generally are about 21 C. The lakes are ice-covered from December to April, and in some years the ice thickness has exceeded 60 cm. Although some decrease in dissolved oxygen occurs in the bottom waters of all lakes in both summer and winter, there is always sufficient oxygen for salmonids in the upper layers. The lakes tend to be acidic, their *p*H ranging from 6.0 to 7.2. Secchi-disc visibility ranges from 3.5 to 4.9 m. The poor supply of nutrients in the general area is reflected in the low values of total alkalinity (9–15 ppm), and total dissolved solids (28–54 ppm) in the waters. Ryder (1965) has shown that a low level of fish production can be expected from lakes of similar fertility.

The study lakes varied widely in their fish species composition (Table 2). Minnows were present in all the lakes and, along with the brook stickleback, were the only resident fish in Little Minnow Lake. The white sucker was present in the other five lakes, and was the only other species in Crevice and Major lakes. In addition to minnows and the white sucker, stunted yellow perch and pumpkinseed were abundant, and the brown bullhead was common in Shrew and Billy lakes. Only Redrock Lake had self-sustaining brook and lake trout populations. Its fish community also included the round whitefish, white sucker, yellow perch, brown bullhead, and four minnow species.

Plantings — Yearlings were planted at rates ranging from 150 fish/ha in the small lakes, to 50 fish/ha in the largest lake. The planting rates were selected after considering the results of planting studies (Smith 1952; Burdick and Cooper 1956; Hatch and Webster 1960; Zilliox and Pfeiffer 1960) in similar waters.

The brook trout used were reared at the Pembroke Trout Rearing Station from eyed eggs produced by domestic stock at the Hills Lake Hatchery. Prior to distribution the fish were fin-clipped, counted into lots, and held for observation for 1–6 days. The fish were anaesthetized with tricaine methanesulfonate (M.S. 222) to facilitate clipping. Samples of fish were dipnetted from rearing troughs, and fork lengths (Table 3) were measured to the nearest 2.5 mm. Also, 2.3-kg lots were counted to determine the mean weight of the fish.

The splake were of the F_1 generation, produced, with one exception, by the fertilization of Lake Manitou lake trout eggs with the sperm of domestic brook trout stock maintained at Tarentorous Hatchery. The 1968 plantings consisted of progeny of a cross between Lake Opeongo lake trout females and domestic brook trout males reared at Chatsworth Hatchery. The splake reared at Tarentorous Hatchery were consistently small, ranging from 8.4 to 8.9 cm mean fork length at the time of planting, whereas those reared at Chatsworth averaged 13.5 cm (Table 3). All lots were fin-clipped at the hatchery several weeks prior to planting.

Rainbow trout yearlings were received from four different rearing stations, but all were progeny of domestic brood stock from Normandale Hatchery. Mean fork lengths of the various planted lots varied from 7.6 to 14.0 cm (Table 3). From 1962 to 1967 the rainbow trout were not fin-clipped prior to planting.

After 1966, few F_1 splake were available for this study, and progeny of the backcrosses of F_1 splake with either brook or lake trout were substituted in Crevice Lake. The mean percent recovery of three plantings of a cross between F_1 male splake and domestic brook trout females, and two plantings of a cross between F_1 male splake and Lake Manitou lake trout females, was only 1.2%. The low recovery is possibly related to their rearing history. Several of these plantings had survived outbreaks of furunculosis (causative organism *Aeromonas salmonicida*) in the hatchery, and the stress imposed in transporting and planting may have been too severe.

The fish planted in Crevice and Major lakes were transported by truck in oxygen-equipped tanks. Plantings allocated to Billy and Redrock lakes were flown to the lakes and released after the float-equipped aircraft landed. Shrew Lake was planted by air-drop. Little Minnow Lake was planted by air-drop, except in 1966 and 1967, when plantings were made by hand. Fish-carrying equipment and loading-rates were described by Fraser (1968). The plantings were made from late April to early June.

METHODS OF RECOVERY

Although anglers accounted for a large percentage of the fish recovered, a heavy exploitation of planted fish was ensured by gillnetting. In Redrock Lake, gillnetting was not required.

Creel Census — The creel-census procedures were similar on all lakes, and consisted of interviewing the angling party and recording the number of anglers, the number of hours of fishing, and the numbers of various species caught. Individual fish were examined for marks or tags, their fork lengths measured to the nearest 2.5 mm, their sex and state of maturity noted, and scale samples collected.

During the open-water season, the creel-checking pattern usually consisted of visiting the lakes each morning, checking any fish from the previous day's fishing,

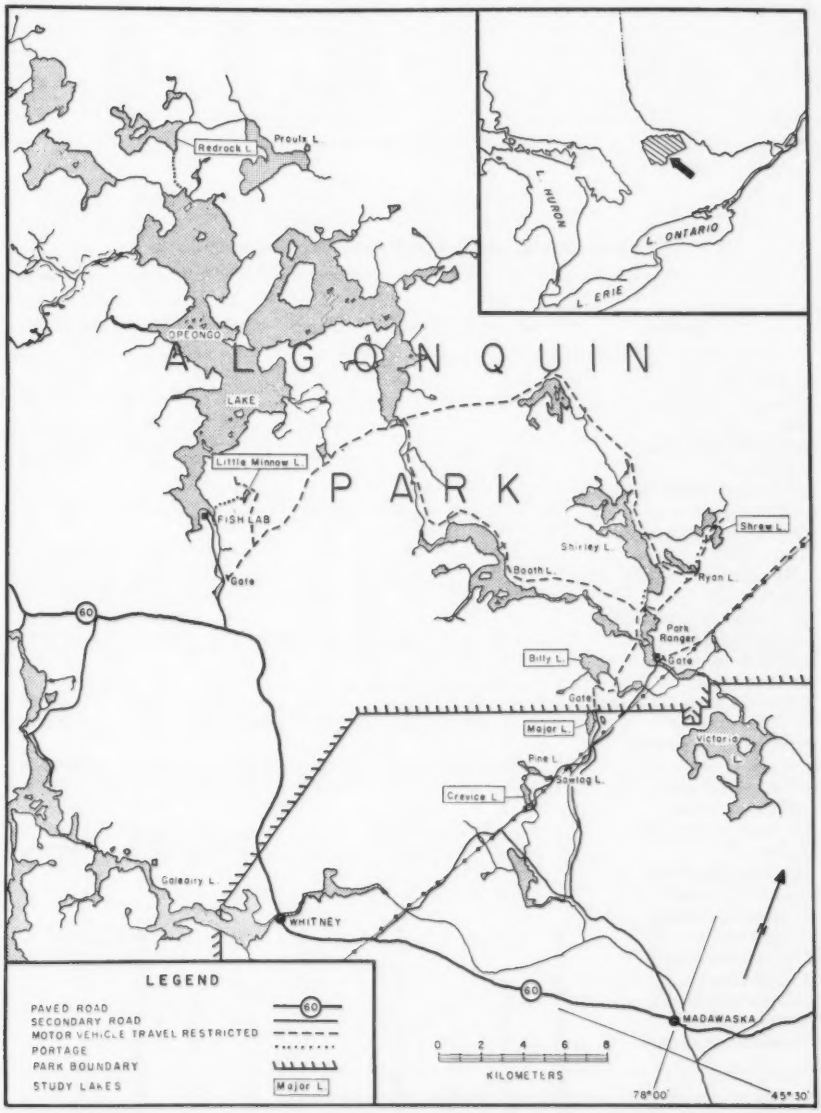

FIG. 1. Locations of the study lakes.

TABLE 1. Characteristics of the study lakes (number of determinations in parentheses).

Lake	Area (*ha*)	Maximum depth (*m*)	Mean depth (*m*)	Secchi disc visibility (*m*)	*p*H	Total alkalinity (*ppm*)	Total dissolved solids (*ppm*)
Little Minnow	8.9	14.3	5.2	3.5(11)	6.0(1)	9(2)	44(2)
Crevice	25.5	18.3	6.1	4.9(31)	6.8(2)	11(6)	44(6)
Major	26.3	14.6	7.3	4.8(12)	7.2(5)	15(4)	54(4)
Shrew	34.8	9.1	5.5	4.5(10)	6.9(2)	12(3)	28(3)
Billy	93.0	8.5	4.6	4.7(13)	6.7(1)	12(3)	47(3)
Redrock	302.1	21.3	8.8	3.7(1)	6.9(2)	12(6)	39(6)

TABLE 2. Species of fish known to occur in the study lakes.

Species	Little Minnow	Crevice	Major	Shrew	Billy	Redrock
Round whitefish (*Prosopium cylindraceum*)	–	–	–	–	–	x
Brook trout (*Salvelinus fontinalis*)	–	–	x[a]	–	x[a]	x
Lake trout (*Salvelinus namaycush*)	–	–	–	–	–	x
White sucker (*Catostomus commersoni*)	–	x	x	x	x	x
Pearl dace (*Semotilus margarita*)	x	x	x	x	x	–
Creek chub (*Semotilus atromaculatus*)	x	x	x	x	x	x
Redbellied dace (*Chrosomus eos*)	x	x	x		x	–
Golden shiner (*Notemigonus crysoleucas*)	x	x	–	–	–	–
Fathead minnow (*Pimephales promelas*)	–	x	–	x	–	–
Common shiner (*Notropis cornutus*)	–	–	x	x	–	x
Blacknose shiner (*Notropis heterolepis*)	–	–	–	–	–	x
Lake chub (*Couesius plumbea*)	–	–	–	–	–	x
Brook stickleback (*Culaea inconstans*)	x	x	x	x	–	–
Yellow perch (*Perca flavescens*)	x[b]	–		x	x	x
Pumpkinseed (*Lepomis gibbosus*)	–	–		x	x	–
Brown bullhead (*Ictalurus nebulosus*)	–	–		x	x	x

[a]Sparse population — natural reproduction extremely limited.
[b]Introduced by bait-dumping in 1967.

TABLE 3. Recoveries by angling and gillnetting of the three salmonids from the study lakes (in the order brook trout, F_1 splake, and rainbow trout). Values in parentheses below the year of planting are mean fork lengths (cm) at planting.

	Year of planting									Year of planting								
	1962 (11.9) (8.4) (8.4)	1963 (11.9) (8.4) (10.7)	1964 (11.9) (8.6) (8.9)	1965 (13.8) (9.4) (8.9)	1966 (14.2) (8.9) (13.5)	1967 (13.7) (8.4)	1968 (15.7) (13.5) (7.6)	1969 (16.5) (13.8)	Mean	1962	1963	1964	1965	1966	1967	1968	1969	Mean
	Little Minnow Lake									Shrew Lake								
Number planted per hectare	79	79	79	79	79	79	159	–	–	44	52	52	104	57	–	–	–	–
	67	79	84	–	59	–	161	–	–	40	49	52	–	–	–	25	–	–
	–	–	–	79	–	79	–	–	–	52	52	–	–	57	40	52	57	–
Percent recovered	17.6	14.6	29.8	8.9	25.0	28.7	14.1	–	19.8	1.0	0.7	3.8	1.3	2.9	–	–	–	1.9
	8.7	14.4	14.9	–	17.9	–	15.4	–	14.3	2.9	1.8	7.9	–	–	–	6.9	–	4.9
	–	–	–	9.0	–	11.9	–	–	10.5	1.1	4.3	–	–	5.3	5.7	2.3	3.6	3.7
Weight planted (*kg*)	10.4	10.4	12.7	21.3	22.7	18.6	63.6	–	–	23.6	27.2	32.7	109.0	64.9	–	–	–	–
	4.5	5.4	5.4	–	4.1	–	35.9	–	–	10.4	13.2	12.7	–	–	–	22.2	–	–
	–	–	–	5.9	–	4.1	–	–	–	11.8	25.4	–	–	53.6	8.6	9.1	75.8	–
Weight caught/weight planted	6.5	3.4	5.1	0.5	1.5	2.5	0.5	–	–	0.2	0.1	0.8	0.1	0.1	–	–	–	0.3
	4.7	7.1	6.3	–	6.9	–	0.9	–	–	1.8	1.9	6.1	–	–	–	0.8	–	2.7
	–	–	–	6.2	–	6.0	–	–	–	–	2.4	–	–	0.8	2.6	1.2	–	1.7
	Crevice Lake[a]									Billy Lake								
Number planted per hectare	62	62	62	94	62	79	59	59	–	25	25	25	–	–	–	–	–	–
	74	79	86	79	–	–	59	–	–	22	25	25	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	25	22	22	–	–	–	–	–	–
Percent recovered	9.0	5.1	12.9	19.9	10.5	20.6	21.1	19.5	14.8	1.4	0.7	4.8	–	–	–	–	–	2.3
	7.7	8.7	8.9	5.7	–	–	5.2	–	7.2	0.2	0.1	0.8	–	–	–	–	–	0.4
	–	–	–	–	–	–	–	–	–	2.4	7.7	1.1	–	–	–	–	–	3.7
Weight planted (*kg*)	24.1	24.1	29.1	72.6	51.8	53.1	68.1	84.9	–	35.0	35.0	41.8	–	–	–	–	–	–
	13.2	14.1	15.4	19.5	–	–	38.6	–	–	13.6	17.7	15.9	–	–	–	–	–	–
	–	–	–	–	–	–	–	–	–	15.0	27.7	15.4	–	–	–	–	–	–
Weight caught/weight planted	0.8	0.7	0.8	0.6	0.2	0.6	0.5	0.4	0.6	0.2	0.1	0.5	–	–	–	–	–	0.3
	3.4	4.1	3.1	1.9	–	–	0.4	–	2.6	0.1	0.1	0.4	–	–	–	–	–	0.2
	–	–	–	–	–	–	–	–	–	1.9	1.3	0.1	–	–	–	–	–	1.1
	Major Lake[a]									Redrock Lake[a]								
Number planted per hectare	62	62	62	62	–	–	62	–	–	25	22	20	25	10	17	–	–	–
	–	–	–	77	–	–	49	–	–	17	25	20	–	–	–	–	–	–
	–	–	22	62	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Percent recovered	5.2	2.8	8.0	4.6	–	–	9.0	–	5.9	0	0.2	0.4	0.2	0.2	0.2	–	–	0.2
	–	–	–	8.2	–	–	9.2	–	8.7	0.3	0.3	0.6	–	–	–	–	–	0.4
	–	–	1.5	2.1	–	–	–	–	1.8	–	–	–	–	–	–	–	–	–
Weight planted (*kg*)	24.1	24.1	29.1	48.6	–	–	72.6	–	–	114	106	109	227	97	134	–	–	–
	–	–	–	19.1	–	–	33.1	–	–	43	55	45	–	–	–	–	–	–
	–	–	4.5	13.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Weight caught/weight planted	0.5	0.4	0.7	0.2	–	–	0.2	–	0.4	0	0.02	0.06	0.02	0.01	0.01	–	–	0.02
	–	–	–	2.1	–	–	1.2	–	1.7	0.4	0.4	0.5	–	–	–	–	–	0.4
	–	–	0.5	1.0	–	–	–	–	0.8	–	–	–	–	–	–	–	–	–

[a]These lakes also received plantings of fall fingerling brook trout in certain years.

if necessary, and arranging for an additional check later in the day. The census workers also contacted the local park ranger, who issued travel permits in the area, to obtain information on the number and location of anglers. During July and August 1967–70, aerial counts of boats on the study lakes were made on three randomly-selected days per week.

Crevice, Major, Billy, and Shrew lakes, being in the same vicinity, were checked by a creel-census crew travelling by truck. Little Minnow Lake is near the research station, and anglers must pass the Lake Opeongo creel-checking station and adjacent boat livery to reach the lake. Approximately 75% of the anglers were interviewed upon their return from the lake. Redrock Lake is reached by a 1.2-mile portage leading from the north arm of Lake Opeongo. Early spring fishing was very popular in Redrock Lake, and over 90% of the catch was taken during the first 4 weeks of the season. During this period, a resident census crew operated exclusively at this lake.

Crevice and Major lakes, which lie just outside Algonquin Park, were open to winter angling from 1965 to 1969. Since the service road was not snow-ploughed, access to the lakes was provided solely by snowmobile during the winter. Each week throughout the winter season, a census worker visited the lakes on one weekend day and three weekdays, selected at random. Most of the winter anglers were local inhabitants from whom the census worker obtained information on nonchecking days as well.

On the basis of information provided by the park ranger, guides, and anglers, combined with the aerial survey data and a knowledge of the pattern of fishing in the area, it is estimated that the census covered about 75% of the angling in the five smaller study lakes, and 90% of the angling in Redrock Lake. Accordingly, the census data for the five small lakes were multiplied by a factor of 4/3, and Redrock data by 10/9, to provide estimates of total angling returns.

Gillnetting — All lakes, except Redrock Lake, were sampled annually with gillnets, usually in mid to late summer, after angling activity had subsided. Redrock Lake was not gillnetted because angling was sufficiently intense to provide a measure of the survival of planted fish; Baldwin (MS 1948) estimated that angling removed approximately 80% of age-groups III–V from the natural brook trout population.

The gillnets, of monofilament nylon, were 16 m long and 1.5 m deep. The net gang consisted of three 16-m sections of 51-, 64-, and 76-mm mesh (stretched measure). Occasionally a 38-mm mesh net was added to the gang. All fish caught were brought to the laboratory for examination.

Recoveries

Little Minnow Lake — Recoveries of all three salmonids were highest in Little Minnow Lake, where the resident population at the beginning of the study consisted of four minnow species and the brook stickleback. Brook trout recoveries ranged from 9 to 30%, averaging 19.8% for the seven annual plantings (Table 3). Approximately 50% of the recoveries were made in the year of planting, and the remainder a year later (Fig. 2). For each kilogram planted, 2.9 kg of brook trout were recovered.

The recoveries from the five plantings of splake in this lake ranged from 8.7 to 17.9%, averaging 14.3% (Table 3). Although the percent recovery was lower than that of brook trout, the weight recovery of splake was greater: 5.2 kg for each kilogram planted.

The two plantings of rainbow trout in this lake yielded returns of 9.0% and 11.9% (Table 3). A few of these fish survived for several years after planting, and their growth contributed to a high weight–recovery ratio of 6.1:1.

Yellow perch were introduced into this lake, apparently through bait-pail dumping, in the mid-1960s, and first appeared in gillnet catches in 1968 (Table 4). In 1969, the gillnets caught 191 perch, comprising 85% of the total weight of fish caught in the gillnets in the lake that year. These fish, members of the 1967 year-class, averaged 200 g in weight. They grew much faster than usual for perch in other small lakes in the area. Perch of the same age-group in nearby Costello Lake weigh 14 g (Langford and Martin 1940). Presumably competi-

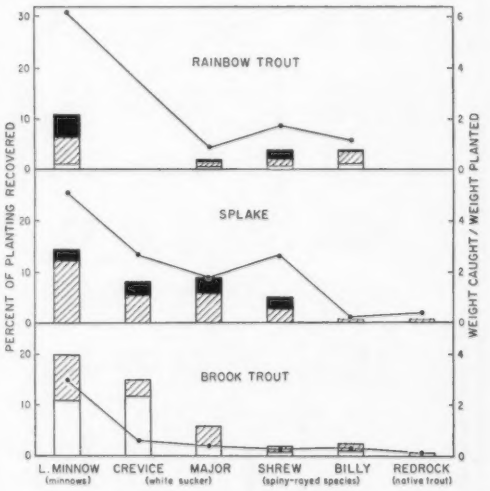

FIG. 2. Mean recoveries (histograms) from annual plantings of the three salmonids in lakes having different resident fishes, and (polygrams) ratios of weight recovered to weight planted. Clear areas in histograms, recoveries in year of planting; hatched areas, in next year; and black areas; in later years. Main resident species in the lakes are shown in parentheses.

TABLE 4. Numbers of fish caught by angling and by gillnetting in the study lakes, 1962–1969. Gillnets were set overnight.

	Angling					Gillnetting					
Year	Angler hours	Fish per angler-hour	Brook trout	Splake	Rainbow trout	Length of net (*m*)	Brook trout	Splake	Rainbow trout	Yellow perch	White sucker
Little Minnow Lake											
1963	227	0.5	96	25	–	730	53	23	–	–	–
1964	472	0.4	105	61	–	365	64	28	–	–	–
1965	573	0.4	130	101	–	490	34	24	7	–	–
1966	487	0.2	81	2	5	730	67	2	17	–	–
1967	537	0.4	143	43	21	580	25	40	6	–	–
1968	640	0.3	164	8	47	365	9	11	17	4	–
1969	952	0.3	111	206	32	685	18	15	6	191	–
Crevice Lake											
1962	354	0.3	95	–	–	885	146	18	–	–	396
1963	771	0.2	96	36	–	730	97	80	–	–	216
1964	908	0.4	312	91	–	550	86	34	–	–	178
1965	1393	0.5	542	206	–	490	51	17	–	–	232
1966	719	0.4	209	53	–	775	84	48	–	–	521
1967	1185	0.4	404	48	–	855	80	25	–	–	388
1968	748	0.4	292	34	–	1115	219	74	–	–	214
1969	700	0.6	335	52	–	–[a]	72	16	–	–	313
Major Lake											
1962	–	–	–	–	–	1130	235	–	–	–	510
1963	290	0.2	57	–	–	930	173	–	–	–	385
1964	305	0.4	129	–	–	900	173	–	1	–	433
1965	542	0.2	112	–	7	745	62	–	2	–	213
1966	597	0.4	163	63	15	1080	25	64	7	–	398
1967	469	0.1	8	33	6	870	20	47	2	–	538
1968	756	0.2	70	66	1	930	141	35	–	–	501
1969	464	0.2	29	42	1	975	49	35	–	–	270
Shrew Lake											
1963	–	–	–	–	–	1220	15	30	7	12	352
1964	–	–	–	–	–	550	42	16	9	2	111
1965	180	0.3	10	38	46	975	73	70	–	7	84
1966	482	0.1	4	34	44	1235	58	7	15	266	60
1967	156	0.3	10	26	44	1035	3	9	20	59	116
1968	296	0.2		12	59	685	–	11	21	9	113
1969	300	0.4		31	95	795	–	26	32	10	69
Billy Lake											
1963	445	0.4	41	–	115	915	71	3	13	176	616
1964	547	0.2	53	–	57	745	32	2	7	122	139
1965	372	0.2	55	–	28	1280	101	19	7	641	311
Redrock Lake											
1961	1978	0.4	730[b]	6[c]	–	–	–	–	–	–	–
1962	933	0.5	448	3	–	–	–	–	–	–	–
1963	Closed to angling										
1964	1360	0.4	530	12	–	–	–	–	–	–	–
1965	713	0.4	243	16	–	–	–	–	–	–	–
1966	Closed to angling										
1967	1635	0.5	680	53	–	–	–	–	–	–	–
1968	1210	0.5	553	1	–	–	–	–	–	–	–

[a]Lake reclaimed with rotenone in September, 1969. Catch is collection of fish after poisoning.
[b]Brook trout catches consist almost entirely of native fish.
[c]Six splake in 1961, 3 in 1962, 3 in 1964, and 1 in 1967 were survivors of plantings made in mid-1950s.

tion with the perch was one of the reasons for the marked decrease in weight-recovery ratios to 0.5:1 and 0.9:1 for the 1968 plantings of brook trout and splake (Table 3).

Crevice and Major Lakes — For Crevice and Major lakes, in which the white sucker was the main resident species, the mean recoveries of brook trout (Table 3) were, respectively, 14.8% (8 plantings) and 5.9% (5 plantings). Splake recoveries averaged 7.2% (5 plantings) and 8.7% (2 plantings), respectively. For the two plantings of rainbow trout, both in Major Lake, the mean recovery was 1.8%.

In Crevice Lake, recovery of brook trout was higher than that of splake because the brook trout were larger at the time of planting and consequently more vulnerable to anglers. When larger brook trout were planted in the later years of the experiment, recoveries by anglers increased (Table 3). In fact, 92% of the brook trout recovered from the 1965–69 plantings in this lake were caught during the year of planting. That the Crevice Lake brook trout fishery was essentially "put and take" angling is borne out by the low return, in weight, of the plantings. The mean weight-recovery ratio of brook trout was 0.6:1, compared to 2.9:1 in Little Minnow Lake, where 50% of the recovered fish spent at least a year in the lake.

Whereas the large size of planted brook trout made them vulnerable to the sport fishery immediately after planting, the small size of the planted splake (8.4–13.5 cm) protected them from fishing mortality during the first year in the lake. Those that escaped natural mortality grew to vulnerable size by the following year. Their growth in the interim is reflected in the weight-recovery ratio of 3.1:1 for splake, compared to 0.6:1 for brook trout in Crevice Lake.

In Crevice Lake, small numbers of brook trout and splake were caught in trapnets each October from 1963 to 1966. These were marked and released to obtain Petersen estimates (Table 5) of the fall populations. In each year, the population consisted mainly of survivors from the spring planting. The population estimates for brook trout ranged from 288 to 91, and those for splake ranged from 260 to 134. Whereas the fall brook trout populations consisted of age-groups I+, the splake populations were made up of age-groups I+ and II+ in 1964 and 1965, and of age-groups II+ and III+ in 1966. The low trapnet catches in the fall, the low population estimates, and the low recoveries by angling and netting all indicate a high natural mortality of planted brook trout and splake in Crevice Lake.

Shrew and Billy lakes — In these two lakes, with spiny-rayed species (yellow perch and pumpkinseed) in addition to white sucker and minnows, brook trout recoveries were low, averaging 1.9% (5 plantings) in Shrew Lake and 2.3% (3 plantings) in Billy Lake (Table 3).

The recoveries from the four splake plantings in Shrew Lake averaged 4.9% (Table 3). Some splake survived 5 years in this lake, and attained weights in excess of 2 kg. Splake were recovered in a ratio of 2.7 kg/kg planted. Only 0.4% of the splake planted in Billy Lake were recovered. The low recovery can be attributed in part to water-temperature conditions in late summer. In

TABLE 5. Fall population estimates of brook trout and splake in Crevice Lake, 1963–66.

Tagging date (Oct.)	Mean length (*cm*)	Marked fish at large	Recapture method	No. recaptured		Population estimate
				Unmarked	Marked	
Brook trout						
1963	23.1	35	angling—1964	30	5	245
1964	22.6	23	winter angling—1965	23	2	288
1965	25.4	20	gillnetting—1966	23	5	112
1965	25.4	20	angling—1966	7	3	67
1966	24.4	17	angling—1967	13	3	91
Splake						
1963	21.1,[a] 35.8	15	gillnetting—1964	31	2	248
1963	21.1, 35.8	15	angling—1964	49	3	260
1964	22.4, 32.3	17	winter angling—1965	115	11	195
1966	31.0, 39.4	41	angling—1967	25	11	134

[a]Two age-groups.

certain years Billy Lake was homothermous at 19 C (J. M. Fraser unpublished data), a situation considered unfavourable for splake. Pearson (MS 1952), in controlled laboratory experiments, determined the preferred water temperature of splake to be 12 C, similar to the lake trout preferendum. Also Burkhard (MS 1962) noted that when the temperatures exceeded 15 C above the thermocline in Parvin Lake, Colo., the splake moved into the cool, deeper areas of the lake.

Recovery of rainbow trout planted in Shrew Lake was similar to that of splake. Only 3.7% were recovered, but a few of these lived for 5 years and weighed 2 kg. Their growth contributed to a weight–recovery ratio of 1.7:1. The percent recovery and weight recovery in Billy Lake were identical to the Shrew Lake values.

Redrock Lake — As stated earlier, there were natural populations of brook and lake trout in Redrock Lake. The angling fishery on this lake was under an experimental system of closure every 2nd year, from 1936 to 1960 (Martin and Baldwin 1953), and every 3rd year from 1961 to 1969. Although the angling catch averaged about 500 brook trout in the "open" years (Table 4) very few were planted stock. The six annual plantings of brook trout yielded only 0.2–0.4% of the numbers planted. The three plantings of splake yielded 0.3–0.6% recoveries. Similar planting experiments with brook trout and splake by Martin and Baldwin (1960) produced similar results.

Planting splake in Redrock Lake may have profound genetic effects on the native brook trout. The few splake that survived their planting year grew rapidly and became less vulnerable to anglers (J. M. Fraser unpublished data). Approximately 25 large splake (50–70 cm fork length) were observed on the spawning area in 1969 and 1970, apparently spawning with the native brook trout. Studies are underway to determine the extent and possible significance of this activity.

Yields

Little Minnow Lake was the only Lake in which the total catch of salmonids exceeded the weight that had been planted. The yields by angling and gillnetting in this lake ranged from 3.9 to 11.7 kg/ha per year, averaging 8.4 kg/ha for the 7 years (Table 6). When the weights of the plantings were subtracted from the total yields, the resulting net yields ranged from 8.7 to –1.9 kg/ha per year, and averaged 3.9 kg/ha per year. The negative net yield of 1.9 kg/ha in 1969 was probably the result of competition from the recently introduced yellow perch and a change in the stocking rate from 150 to 320 fish/ha.

The populations of resident fish in the other study lakes evidently limited the survival and growth of the planted salmonids. The mean total yields ranged from 0.6 to 2.6 kg/ha per year and were less than the weight of salmonids planted annually in these lakes.

The gillnet catches of white suckers (Table 4) in four of the five lakes in which the species was resident, represented mean annual removals of 3.7, 3.4, 1.7, and 3.0 kg/ha from Crevice, Major, Shrew, and Billy lakes, respectively. The catches of yellow perch in the gillnets largely represented incidental captures, except in Little Minnow Lake in 1969. Here, members of the initial year-class of perch (introduced) had grown rapidly and become vulnerable to the mesh sizes in use. Stunted yellow perch were abundant in Shrew and Billy lakes, but the mesh sizes commonly used (i.e. 51 mm stretched measure) were too large to capture these small fish. As an indication of the numbers of perch present in Billy Lake, 60 m of 38-mm mesh gillnet set overnight in 1965 caught 521 perch approximately 16 cm in length. Small numbers of pumpkinseed, brown bullhead, and creek chub were also taken in the gillnets.

Discussion

Recoveries of the planted salmonids were related to the composition of the fish fauna in the different lakes (Fig. 2). Recoveries were highest (9–30%) for Little Minnow Lake, where the resident minnows and sticklebacks apparently offered the least competition and predation. Recoveries were considerably less (2–15%) for plantings in Crevice and Major lakes, which had native populations of white sucker, and still lower (0.5–5%) for Shrew and Billy lakes, which were inhabited by spiny-rayed species as well as the white sucker. Lowest recoveries of all (<0.5%) were recorded for the splake and brook trout plantings in Redrock Lake, which had native populations of brook and lake trout in addition to competitor species. In one instance, when the opening of angling in Redrock Lake coincided closely with a planting of yearling brook trout, appreciable numbers of the latter were found in the stomachs of both native brook trout and native lake trout.

The assumption that survival of the planted trout was influenced by the compositions of the resident fish populations is supported by various reports. Rawson's (1948) studies in western Canada suggested that there was little use in planting rainbow trout in lakes already heavily populated with

predator and competitor species. Rawson and Elsey (1950) noted that 10 years of continuous planting with rainbow trout failed to provide angling for this species in Pyramid Lake, Alta., and they considered that longnose suckers (*Catostomus catostomus*) and mountain whitefish (*Prosopium williamsoni*) were competing for the available food. Wales (1946) attributed the low survival of brown (*Salmo trutta*), rainbow, and brook trout fingerlings in Castle Lake, Calif., to predation by larger trout. After the predators were removed by poisoning, the survival of fingerling brook trout increased from an average of 1.9% to approximately 35% (Wales and German 1956). Smith (1938) reported that the poisoning of yellow perch and other species in three Nova Scotia lakes created more suitable conditions for brook trout, and (1952) suggested that competition and predation

TABLE 6. Yields (kg) by angling and gillnetting of the three salmonids from five of the study lakes, 1962–69.

Year	Weight[a] planted (*kg*)	Brook trout		Splake		Rainbow trout		Yield (*kg/ha*)	
		Angling	Netting	Angling	Netting	Angling	Netting	Total	Net
Little Minnow Lake (8.9 *ha*)									
1963	25.4	49.9	20.4	14.1	8.6	–	–	10.4	7.6
1964	18.2	34.1	10.9	20.0	10.0	–	–	8.4	6.4
1965	26.8	48.1	12.7	32.7	10.0	–	0.9	11.7	8.7
1966	28.6	10.0	10.4	2.3	2.3	1.8	7.7	3.9	0.7
1967	22.7	28.6	4.5	8.2	12.3	13.6	4.1	8.0	5.5
1968	67.6	37.7	1.8	5.0	4.1	14.1	5.0	7.6	0
1969	98.1	28.6	2.7	30.9	2.7	15.0	0.9	9.1	–1.9
Crevice Lake (25.5 *ha*)									
1962	24.1	19.1	15.0		1.4	–	–	1.3	0.4
1963	47.7	11.4	14.5	7.7	24.5	–	–	2.2	0.4
1964	56.3	38.6	10.9	24.5	11.4	–	–	3.4	1.1
1965	104.9	45.4	5.9	55.8	4.5	–	–	4.4	0.2
1966	89.4	11.4	11.4	20.4	11.4	–	–	2.1	–1.3
1967	67.2	30.0	8.2	19.5	8.6	–	–	2.6	0
1968	130.3	23.1	22.7	5.9	11.8	–	–	2.5	–2.6
1969	149.8	39.0	11.8	7.7	5.9	–	–	2.5	–3.4
Major Lake (26.3 *ha*)									
1962	35.4	–	29.1	–	–	–	–	1.1	–0.2
1963	35.4	10.9	21.0	–	–	–	–	1.2	–0.1
1964	50.4	18.1	32.4	–	–	–	0.1	1.9	0
1965	97.6	17.7	7.6	–	–	2.2	0.3	1.1	–2.7
1966	–	16.9	2.7	8.0	11.5	5.4	2.8	1.8	1.8
1967	–	1.5	3.5	6.5	11.7	3.0	1.0	1.0	1.0
1968	123.5	4.5	13.3	29.3	2.8	0.5	–	1.9	–2.8
1969	–	5.0	6.7	7.8	12.6	1.8	–	1.2	1.2
Shrew Lake (34.8 *ha*)									
1963	65.8	–	5.1	–	6.3	–	3.9	0.4	–1.3
1964	99.0	–	9.4	–	10.8	–	5.7	0.7	–2.0
1965	109.0	4.5	24.2	17.1	30.0	35.5	–	3.0	0
1966	118.5	1.1	9.1	23.2	7.5	12.9	1.9	1.6	–1.8
1967	8.6	3.9	1.4	17.7	8.3	34.4	12.1	2.1	1.9
1968	30.4	–	–	8.9	5.3	24.7	9.4	1.3	0.4
1969	75.8	–	–	10.3	8.2	34.0	8.4	1.7	–0.4
Billy Lake (93.0 *ha*)									
1963	63.6	15.9	26.8	–	1.0	26.3	5.9	0.8	0.1
1964	80.4	14.1	3.2	–	0.5	20.0	3.6	0.4	–0.4
1965	73.1	11.8	22.2	–	6.4	11.8	2.7	0.6	–0.2

[a]Includes brook trout planted in year "*n*" plus splake and rainbow trout planted in year "*n*-1".

by other fish were responsible for the low survival of trout in certain New Brunswick lakes. Eschmeyer (1938) noted that the stocking of brook trout in four Michigan lakes which contained yellow perch was uniformly unsuccessful, whereas planted trout grew and survived well in four adjacent lakes that contained only forage fish. Hayes and Livingstone (1955) demonstrated that a small increase in the standing crop of brook trout in a Nova Scotia lake resulted from the partial poisoning of yellow perch and creek chub. Zilliox and Pfeiffer (1960), in their account of the reclamation of 100 lakes in New York State between 1950 and 1960, stated that the presence of yellow perch and other introduced species usually made it impossible to sustain a successful brook trout fishery, even with legal-size stocking.

In most instances more splake and rainbow trout than brook trout survived in the Algonquin Park lakes. Only in Little Minnow Lake did appreciable numbers of planted brook trout survive over winter. In contrast, nearly all the splake recovered from the various lakes had lived 1 year, and a few had survived as many as 5 years in the wild. Rainbow trout also survived for similar periods. The longer survival periods of splake and rainbow trout resulted in net gains in weight, whereas there was a net loss in nearly all brook trout plantings.

Greater survivals of planted rainbow trout than of brook trout have been reported for lakes elsewhere. Wales (1946) found that the survival to the creel was higher for rainbow trout than for brook trout that were planted as fingerlings in Castle Lake, Calif. Hatch and Webster (1960) stated that rainbow trout appeared better suited than brook trout in certain Adirondack lakes. Alexander and Shetter's studies (1961, 1969) of matched plantings in a 16-acre reclaimed lake in Michigan demonstrated a much greater overwinter survival of rainbow trout than of brook trout.

Studies in Ontario waters indicate a wide range of recovery of planted splake. In the present study it was 14% in a lake inhabited by minnows, 8% in lakes inhabited by suckers, 5% in lakes containing spiny-rayed species, and practically nil in a lake occupied by native trout. Martin and Baldwin (1960) found that in nine lakes the recovery of planted splake was less than 2%, but in Jack Lake 75% of the initial planting was recovered. Jack Lake was the only lake which lacked a resident fish population at the time of planting. More recently Berst and Spangler (1970) reported an 8.4% recovery, by sport and commercial fisheries, from a planting of 49,000 F_1 yearling splake at one location in Lake Huron.

It is noteworthy that splake made a greater net gain in weight when they cohabited with spiny-rayed species rather than with suckers only. In Shrew Lake, the only one that allowed the comparison, they were apparently able to forage on the abundant stunted perch, pumpkinseed, and various minnow species. The weights, in excess of 2 kg, attained by a few splake that survived up to 5 years in Shrew Lake, were paralleled in a study by Zilliox and Pfeiffer (1960); they reported splake in their fifth growing-season attaining weights in excess of 2 kg in Adirondack waters containing forage fish.

Undoubtedly, considerable numbers of the planted fish fell prey to fish-eating birds and mammals. Algonquin Park is a wilderness area, inhabited by predators such as the common loon, American merganser, great blue heron, osprey, kingfisher, otter, and mink. These birds and mammals are regularly observed foraging in the study area. Loons are especially noticeable, and nest on at least four of the study lakes. Their relationship to planted salmonids is being investigated. Other investigators (Smith 1955; Johnson and Hasler 1959; Hatch and Webster 1960; Shetter and Alexander 1969) have suggested that predation by fish-eating birds and mammals drastically reduces survival of planted trout in lakes. Schuck (1948) and Vincent (1960) have pointed out that hatchery-reared trout possess inherent traits, such as schooling tendency, lack of wariness, surface response, and lack of foraging experience, which may place them at a definite disadvantage when they are required to make a rapid adjustment to conditions in the wild.

It is unlikely that movement of planted fish from the lakes was an important loss in our study. Except for Crevice Lake, all are headwater lakes with only a few small seasonal inlets. The outlets of the lakes are blocked by aggregations of boulders and beaver dams. Outflow is slight except during the spring freshet, when water cascades over the barriers and dams. Since most plantings were made after the freshet had subsided, the opportunity for migration of yearlings was minimal. Examination of angler's catches and intensive gillnetting in connected lakes revealed few migrants. A fish trap installed just downstream, in the outlet from Crevice Lake, caught only one planted brook trout in two years of operation. Burkhard (MS 1962) concluded on the basis of downstream trap catches that splake and rainbow trout showed little or no tendency to migrate from Parvin Lake (25 ha) in Colorado. In the present study, few planted fish survived to reach maturity and the wandering urge associated with it, as did the brook

trout planted in the fall by Smith (1967) in Crecy Lake, N.B.

Increasing the size of fish planted had different effects in different lakes. In Little Minnow Lake it changed the fishery from a "put to grow" to a "put and take" basis (Fig. 3). The small brook trout planted in Little Minnow Lake from 1962 to 1964 (Table 3) were taken mainly in the year after planting, whereas the larger fish planted after 1964 were taken chiefly in the year they were planted. Lack of competition in Little Minnow Lake in earlier years allowed a significant number of the smaller fish to survive into their second year.

In contrast, the increase in size of planted brook trout in Crevice Lake resulted in a doubling of the percentage recovered in the year of planting (Fig. 3), and few survived into the 2nd year. During the years 1962–64, the average recovery was 9%, whereas during 1965–68 it was 18%. Failure of the fish to survive into their 2nd year was probably due to keen competition with the white suckers. Thus the fishery could only operate on a "put and take" basis.

Increasing the planting rate did not increase yield rate. When the planting rate of splake in Little Minnow Lake was doubled in 1968, although the percent recovery remained the same as from 1962 to 1966 (15% vs. 14%) the weight-recovery ratio decreased from a mean of 6.3, to 0.9 kg per kilogram planted. (Fig. 4). A concurrent doubling of the planting rate of brook trout in the same lake resulted in a decrease in the weight-recovery ratio

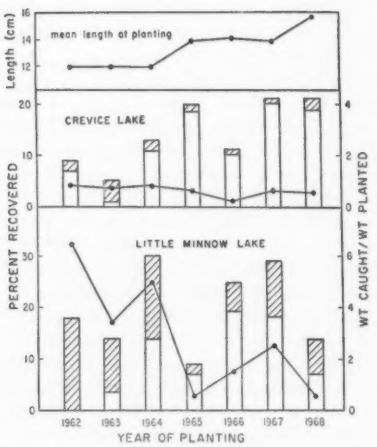

FIG. 3. Recoveries (histograms) of yearling brook trout from Little Minnow and Crevice lakes, along with sizes of fish planted, and (polygrams) ratios of weight recovered to weight planted. Histograms as in Fig. 2.

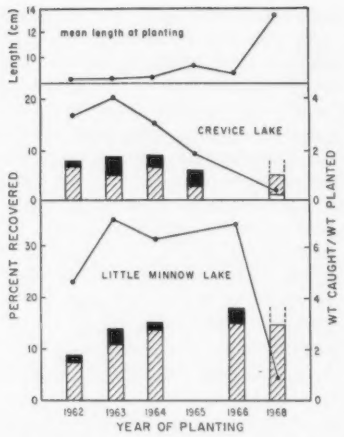

FIG. 4. Recoveries (histograms) of yearling splake from Little Minnow and Crevice lakes, along with sizes of fish planted, and (polygrams) ratios of weight recovered to weight planted. Histograms as in Fig. 2. The unfinished portions of the 1968 histograms indicate fish are still to be recovered.

from a mean of 3.1:1 for 1962–67, to 0.5:1 for 1968, and also resulted in a decrease in percent recovery from a mean of 21% to 14% (Fig. 3). The decreases in the weight-recovery ratio of the two species upon doubling the planting rate suggest that the carrying capacity of the lake was exceeded. However the situation is confused by the appearance of a yellow perch population in the lake that year.

The total yields from the study lakes (0.6–8.4 kg/ha per year) are comparable to the yields of brook and rainbow trout given by other authors for waters generally similar in physical and chemical features. Smith (1952) reported, for brook trout, a mean yield of 0.7 kg/ha from certain New Brunswick lakes and 1.0 kg/ha from Nova Scotia lakes that contained competitive, and in some instances, predatory, species. Hatch and Webster's (1960) studies on four reclaimed Adirondack lakes showed a mean yield of 4.9 kg/ha of brook trout. Castle Lake in California yielded 11.5 kg of brook trout per hectare per year after reclamation (Wales and German 1956). Burdick and Cooper (1956) recorded a mean annual angling yield of 8.1 kg/ha of planted rainbow trout from Weber Lake, Wisconsin.

The only study lake to show a positive mean net yield (i.e. total yield exceeded the weight of fish planted) was Little Minnow Lake, with a mean of 3.9 kg/ha per year of rainbow, splake, and brook trout combined (Table 6). The net yield from Crevice Lake, for example, was 0.7 kg/ha per year

less than the weight planted annually. In most instances the negative net yield from a lake was due to the low survival of brook trout.

The present study substantiates the general conclusion reached in other studies, reviewed by Cooper (1959), that the best returns from planted trout are likely to occur where there is little or no competition from fish already present in the water. Our study lakes are relatively small, infertile, and of simple morphometry. In all but the simplest, planted trout presumably encounter keen competition for the limited food supply of bottom invertebrates. Only in Little Minnow Lake did the mean recovery of all planted species exceed 10%. Evidence suggests that the mean total yield of 8.4 kg/ha per year from this lake is the highest that can be expected from such waters.

Acknowledgments

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Growth Per Moult of Tagged Lobsters (*Homarus americanus*) in Bonavista Bay, Newfoundland

G. P. ENNIS

Fisheries Research Board of Canada
Biological Station, St. John's, Nfld.

ENNIS, G. P. 1972. Growth per moult of tagged lobsters (*Homarus americanus*) in Bonavista Bay, Newfoundland. J. Fish. Res. Bd. Canada 29: 143–148.

The suitability of the sphyrion tag for lobster growth studies is demonstrated by comparing growth of ferromagnetic-and sphyrion-tagged lobsters. Carapace length and total weight increments in one moult of 54 males (52–92-mm carapace length) tagged with sphyrion tags averaged 11.4 mm (15.7%) and 185.9 g (60.8%). For 56 females 57–89-mm carapace length they averaged 9.8 mm (13.3%) and 136.3 g (42.5%). Differences in growth per moult between sexes increased with size. For both sexes percent carapace length increment decreased with increase in carapace length but more rapidly for females. Carapace length increment increased with increasing carapace length for males, but for females there was no significant change over the size range considered. Incidence of moulting for sphyrion-tagged lobsters was 83.1% and comparable with an observed estimate (85.2%) from field samples obtained shortly after the moulting season.

ENNIS, G. P. 1972. Growth per moult of tagged lobsters (*Homarus americanus*) in Bonavista Bay, Newfoundland. J. Fish. Res. Bd. Canada 29: 143–148.

Une comparaison de la croissance à l'aide de marques ferromagnétiques et de marques "sphyrion" démontre la valeur de ces dernières pour l'étude de la croissance du homard. L'accroissement en longueur de carapace et en poids total au cours de la mue chez 54 mâles de 52–92 mm de longueur de carapace et munis de marques "sphyrion" est de 11.4 mm (15.7%) et 185.9 g (60.8%). Les valeurs correspondantes pour 56 femelles de 57–89 mm de longueur de carapace sont de 9.8 mm (13.3%) et 136.3 g (42.5%). L'écart de croissance par mue entre mâles et femelles augmente en proportion de la taille. Chez les deux sexes, le pourcentage d'accroissement linéaire de la carapace diminue en proportion de l'augmentation de la longueur de la carapace, mais la diminution est plus rapide chez les femelles. L'accroissement linéaire de la carapace augmente en proportion de la longueur de la carapace chez les mâles, mais il n'y a pas de changement appréciable chez les femelles, dans les limites de tailles étudiées. L'incidence de la mue des homards munis de marques "sphyrion" est de 83.1%, chiffre comparable à l'estimé de 85.2% observé sur des échantillons recueillis sur le terrain peu de temps après la saison de mue.

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MOST information on growth of American lobsters in nature has been obtained using a marking technique that involves punching or boring holes in various parts of the tail fan of the lobster (Wilder 1948, 1953, 1963; Squires 1970). In the present study two different tagging techniques were used to obtain growth data from lobsters in nature. One was a ferromagnetic tag (Jefferts et al. 1963; Bergman et al. 1968) which, because of its very small size and its position and method of insertion, would reduce to a minimum any retarding effect tags may have on growth of lobsters. It was assumed that this tag would yield lobster growth data very close to that attained under natural conditions. The other was the sphyrion tag (Scarratt and Elson 1965) that has recently become widely used (Scarratt 1970; Cooper 1970; Cooper and Uzmann 1971). This paper compares lobster growth data obtained using the two types of tags and presents in some detail those obtained using the sphyrion tag.

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Materials and Methods

TAGS

The sphyrion tag was similar to that used by Cooper (1970) and the method of insertion similar to that described by him and by Scarratt (1970). The ferromagnetic tag was a 2.5–3-mm long piece of type 302 (.01 inch diam) magnetized stainless steel wire. Each tag was marked with a coloured epoxy stripe. Ten colours were used, each representing a 2-mm length group of lobsters starting at 68–69-mm carapace length. Carapace length measurements were from the eye

socket parallel to the mid-dorsal line to the posterior edge of the carapace. The tags were inserted into the basis muscle of one of the second pleopods with a No. 19 hypodermic needle fitted with a wire plunger. They were detected by passing the lobsters over a magnetometer.

Tagging

In June–July 1967, before the start of the moulting season that lasts from about late July to early September, 234 uninjured lobsters were trapped in plastic igloo lobster pots on commercial grounds near St. Chads, Bonavista Bay, held in wet seaweed for 1–2 hr, then tagged with ferromagnetic tags and released while still vigorous. They were released on the lobster grounds around a small island surrounded by deep (50 fath) cold water in an attempt to prevent them from dispersing over a wide area so that recaptures could be made more readily, following the moulting season, by concentrating trapping and scuba diving in a small area. Observations by scuba diving revealed that the lobsters appeared to be no more concentrated than on nearby grounds. Another 89 lobsters were tagged with ferromagnetic tags and 258 with sphyrion tags in June–July of 1968 before the 1968 moulting season, and an additional 442 lobsters with sphyrion tags in August–October 1968 during and following the moulting season. Sphyrion tags were applied immediately and the lobsters released where they were caught. Most sphyrion tag recaptures were made by fishermen during the 1969 season, which lasts from April 20 to July 15 in this area. A $1.00 reward was paid to the fishermen for letting us examine each tagged lobster. Some tagged lobsters were purchased from fishermen and released on the grounds again during the 1969 fishing season. More recaptures were made during the 1970 fishing season. Recaptures were also made at different times of the year throughout the period while scuba diving.

Data analysis

For lobsters tagged with ferromagnetic tags the midpoint of the length group was taken as the carapace length before moulting. Recaptured lobsters were measured to the nearest millimeter. For lobsters tagged with sphyrion tags measurements before and after recapture were to the nearest millimeter. In each tagging experiment a few lobsters were found that had moulted twice. Their growth increments were so much greater than even the largest increment found in single moulters (at liberty for one moulting season only) that no difficulty was found in separating them on this criterion alone, additionally all had been at liberty over two moulting seasons. Furthermore, if it is assumed that all lobsters of a given sex and tag type, and which moulted during a period of liberty over only one moulting season, make up a homogeneous group of single moulters with their pre- and post-moult sizes distributed as a bivariate normal distribution, the probability of all lobsters classified as double moulters belonging to this group would be in all cases less than one in a thousand.

The number of double moulters (27 in all) was too small for adequate regression analysis and are not considered further in this paper. The indications are however, that the regression lines of double moulters are parallel to those of single moulters. For single moulters post-moult and pre-moult carapace lengths were fitted by arithmetic least squares for each sex and each tag in each year. Comparisons of slopes and intercepts were made by covariance analysis. Estimates of weight gain on moulting were made using the carapace length–total weight relation equation for St. Chads lobsters (Ennis MS 1971).

Results

Comparison of Growth Data from Ferromagnetic and Sphyrion Tags

Growth increments for each sex, tag, and year are given in Table 1. The covariance analysis showed no difference in growth between sphyrion-tagged and ferromagnetic-tagged lobsters for either sex in 1968. For ferromagnetic-tagged lobsters of both sexes there was no difference in growth between 1967 and 1968. Likewise for male sphyrion-tagged lobsters there was no difference in growth between 1968 and 1969, but for female sphyrion-tagged lob-

Table 1. Growth per moult of tagged lobsters recovered from St. Chads grounds 1967–69.

Experiment	Moulting season	Sex	No. recaptured	No. moulted	Avg pre-moult carapace length (*mm*)	Avg carapace length increment (*mm*)
Ferromagnetic tags	1967	M	22	19	75.5	11.7
" "	1967	F	34	33	75.5	9.8
" "	1968	M	15	15	76.4	10.8
" "	1968	F	21	20	77.8	10.2
Sphyrion tags	1968	M	31	26	69.9	10.7
" "	1968	F	40	33	72.3	9.7
" "	1969	M	52	28	75.3	12.0
" "	1969	F	42	23	75.3	9.9

sters there was a slight difference ($P = .042$) between 1968 and 1969. When ferromagnetic tagging data for 1967 and 1968 were combined (Fig. 1), and compared with the sphyrion tagging data for 1968 and 1969 combined (Fig. 2), there was no significant difference for either males or females.

Carapace Length and Total Weight Increments on Moulting

Male lobsters grew more in carapace length and in total weight at moulting than females of the same carapace length and the differences tended to increase with increasing length (Fig. 2 and 3; Table 2). For males at 56–60-mm carapace length, average length and weight increments per moult were 10.5 mm (17.5%) and 107.8 g (67.7%) and for females they were 9.0 mm (15.6%) and 79.8 g (52.0%); at 81–85 mm they were 13.0 mm (15.9%) and 268 g (62.2%) for males and 9.9 mm (12.0%) and 166.5 g (38.8%) for females. For both sexes the percent carapace length increment decreased with increase in carapace length, but more rapidly for females than for males. Percent weight increment decreased with increasing carapace length for females, but for

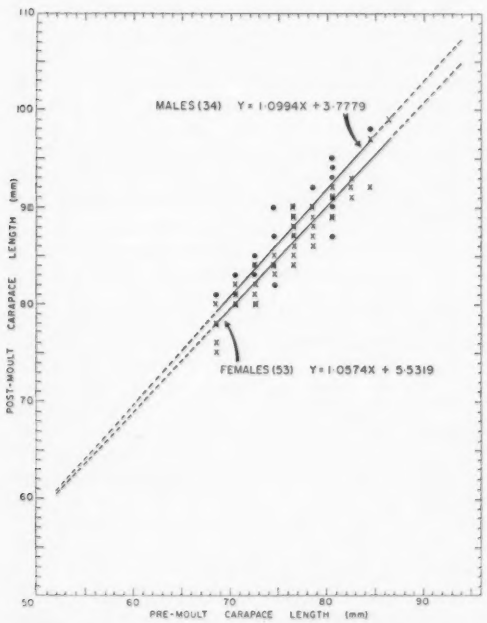

Fig. 1. Growth per moult of male (●) and female (×) lobsters tagged with ferromagnetic tags in 1967 and 1968. (All points not visible on graph because many are superimposed on each other).

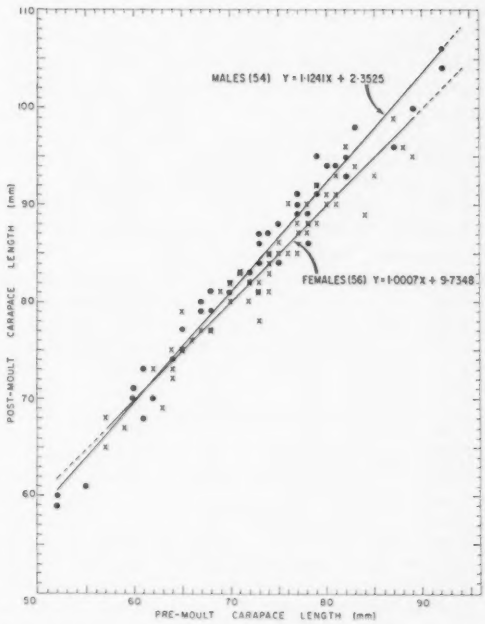

Fig. 2. Growth per moult of male (●) and female (×) lobsters tagged with sphyrion tags in 1968 and 1969. (All points not visible on graph because many are superimposed on each other).

males it increased up to the 81–85 mm carapace length group but for larger sizes (few data are available) it decreased.

The differences in carapace length increment between males and females 56–65-mm carapace length were not significant ($t = .42$, df = 16, $P > .6$), but at 66–75 mm ($t = 3.94$, df = 42, $P < .01$) and at 76–90 mm ($t = 3.39$, df = 41, $P < .01$) the differences were significant. A significant correlation ($r = .5195$; df = 52; $P < .001$) between pre-moult carapace length and carapace length increment was obtained for males, indicating that the increment increased with carapace length (Fig. 3); for females no significant correlation was obtained ($r = .2619$; df = 54; $P = .05$), indicating that there was no significant change in the increment over the 56–90 mm-carapace length range (Fig. 3).

Moulting Incidence

Visual examination of 229 lobsters following the moulting season in 1967 gave a moulting incidence of 85.2%. The moulting incidence of males and females tagged with sphyrion tags was 83.1% during the 1968 moulting season and during the 1969 moult-

TABLE 2. Average carapace length and total weight increments in one moult of male and female lobsters tagged with sphyrion tags in 1968 and 1969.

Length group (*mm*)	Pre moult		Post moult		
	Length (*mm*)	wt (*g*)	length increment (*mm*)	Wt increment (*g*)	No.
			Males		
51–55	53.0	103.2	7.0	51.6	3
56–60	60.0	154.7	10.5	107.8	2
61–65	63.0	181.9	9.8	111.9	6
66–70	68.6	240.2	11.6	160.8	10
71–75	73.0	294.5	11.4	180.3	12
76–80	78.2	369.4	12.5	231.5	13
81–85	82.0	430.9	13.0	268.2	4
86–90	88.0	543.3	10.0	231.0	2
91–95	92.0	628.5	13.0	341.2	2
			Females		
56–60	57.7	155.5	9.0	79.8	3
61–65	63.9	208.4	9.9	107.4	7
66–70	68.2	252.2	10.2	124.6	9
71–75	73.2	308.8	9.1	123.6	13
76–80	77.9	368.2	10.5	161.5	14
81–85	82.4	433.8	9.9	166.5	7
86–90	88.0	523.0	8.7	162.3	3

TABLE 3. Moutling incidence at different sizes for sphyrion-tagged lobsters 1968 and 1969. (Lobsters handled by fishermen in 1969 not included).

Length group (*mm*)	No. males		No. females	
	recaptured	moulted	recaptured	moulted
51–55	2	2	...	...
56–60	3	2	3	2
61–65	6	6	7	7
66–70	9	9	8	8
71–75	13	11	10	10
76–80	10	9	17	13
81–85	3	2	8	5
86–105	5	1	5	1

ing season it was 54.3%. Adverse conditions such as handling have caused inhibition of moulting in lobsters (Stewart and Squires 1968), and it is likely that the much lower moulting incidence in 1969 resulted from the fact that almost half the lobsters on which the estimate was based were handled by fishermen during the 1969 fishing season. These lobsters, which were caught from April 20 to July 15

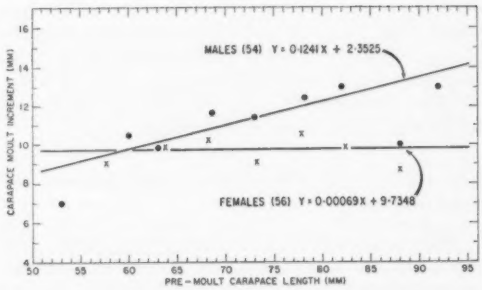

FIG. 3. Carapace length increments per moult of male (●) and female (×) lobsters tagged with sphyrion tags in 1968 and 1969. (Data grouped in 5-mm length groups).

(before the moulting season), were held by fishermen up to 4 days before they were purchased by FRB field staff with the tags still attached and returned to the fishing grounds. The moulting incidence (30.6%) of these lobsters, during the following moulting season, was considerably less than the moulting incidence (76.9%) of those that avoided capture during the fishing season.

The difference between moulting incidence of sphyrion-tagged lobsters in 1968 (83.1%) and those that avoided capture by fishermen in 1969 (76.9%) is because the average size of lobsters, which yielded the estimate of moulting incidence in 1969, was larger than that on which the 1968 estimate is based (Table 1). For males this difference was significant ($t = 2.35$, df = 52, $P = .02$) and there was some indication that incidence of moulting decreased with increasing size (Table 3).

Discussion

Growth of sphyrion-tagged lobsters in nature is close to that attained by lobsters under completely natural conditions. This was demonstrated by the similarity of moult increments of sphyrion-tagged and ferromagnetic-tagged lobsters. Ferromagnetic tags are minute and unlikely to affect natural growth. Sphyrion tags have advantages over ferromagnetic tags in that they can be seen by fishermen and individually numbered. Cooper (1970) and Scarratt (1970) also demonstrated that natural growth of lobsters was largely unaffected by sphyrion tags and in addition, tag retention was high.

Within the 50–90-mm carapace length range, males grow more at moulting than females. This confirms earlier studies by Wilder (1953, 1963) and Squires (1970) on lobsters within this size but from different areas. The difference is attributed to attainment of sexual maturity. Apparently egg production has a

greater stunting effect on growth than sperm production (Templeman 1933, 1948). Cooper (1970), however, found no difference in growth between sexes of similar size in inshore Gulf of Maine waters. In deep-sea populations on the outer continental shelf off New England, males grow slightly more than females at moulting (Cooper and Uzmann 1971). There are also differences in growth per moult of lobsters in different areas. In the southern Gulf of St. Lawrence, growth in carapace length and total weight of lobsters (males and females combined), approximately 50–70-mm carapace length (Wilder 1953), was considerably less than males and slightly less than females in Bonavista Bay. In lobsters approximately 70–90-mm carapace length in southern Nova Scotia and Grand Manan, Wilder's (1953) figures were less than males and slightly more than females in Bonavista Bay. Lobsters approximately 54–63-mm carapace length in Egmont Bay, P.E.I. (Wilder 1963), where males and females were separated, were greater than both males and females of the same length in Bonavista Bay. Over this length range Wilder found moult increments to be independent of size. Carapace length increments of male and female lobsters 74–100-mm carapace length in Port au Port Bay, Nfld. (Squires 1970) were less than those of Bonavista Bay. However, Squires found the same changes in carapace length increment and percent increment with increasing size as found in Bonavista Bay. Cooper's (1970) calculated moult increment for average size (90 mm) Gulf of Maine lobsters (males and females combined) was less than that of males and greater than that of females in Bonavista Bay. Moult increments for deep-sea lobsters off New England (Cooper and Uzmann 1971) were considerably greater than coastal Gulf of Maine lobsters as well as other coastal populations including Bonavista Bay. Templeman (1944) showed that sexual maturity in lobsters was attained at smaller sizes in warm than in cold-water areas. This could account for differences in growth per moult for lobsters of similar sizes in different areas.

Thomas (1958) and Hepper (1970), using the tail punch method on European lobsters (*H. vulgaris*), reported moult increments similar to those reported for *H. americanus*. Other studies (Gibson 1967; Hepper 1967; Simpson 1961), using the same marking method, gave considerably smaller moult increments for *H. vulgaris*. They also found differences between sexes similar to those reported for *H. americanus*. Thomas (1958), Simpson (1961), and Hepper (1970) also found a declining percentage increment as size increased with the decrease more pronounced in females. Hepper (1967) found no significant correlation between original carapace length and moult increment for males, suggesting that the increment is independent of original carapace length. For females, however, he found a significant inverse relation between original carapace length and moult increment indicating that larger females grow less at moulting than small lobsters. This is different from the results of the present study where the increment increased with increasing carapace length for males and was more or less constant for females. Other studies (Gibson 1967 and Hepper 1967) on *H. vulgaris* and (Wilder 1963) on *H. americanus* have shown increments to be more or less constant for both males and females over the size ranges that were considered. All these comparisons indicate that in both *H. americanus* and *H. vulgaris* the patterns of growth and moult increments are quite variable.

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I wish to thank Dr H. J. Squires for suggesting the adaptation of the ferromagnetic tag for use on lobsters, and under whose supervision the study was started and carried out until 1968. Messrs G. E. Tucker and G. Dawe provided assistance in the field and in the laboratory. Mr E. J. Sandeman programmed the covariance analysis, made helpful suggestions in treatment of the data and critically read the manuscript as did Dr W. Templeman.

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Fish Viruses: Histopathologic Changes Associated with Experimental Channel Catfish Virus Disease

KEN WOLF AND ROGER L. HERMAN[1]

Bureau of Sport Fisheries and Wildlife
Eastern Fish Disease Laboratory, Kearneysville, West Virginia 25430, USA

AND C. P. CARLSON

Bureau of Sport Fisheries and Wildlife
Fish Farming Experimental Station, Stuttgart, Arkansas 72160, USA

WOLF, K., R. L. HERMAN, AND C. P. CARLSON. 1972. Fish viruses: histopathologic changes associated with experimental channel catfish virus disease. J. Fish. Res. Bd. Canada 29: 149–150.

A histologic examination was carried out on fry with experimentally induced channel catfish virus disease (CCVD). The infection produced a hemorrhagic and necrotic disease with the target organs being the kidneys, liver, digestive tract, and skeletal muscle. The results agree with symptoms of the disease and with published data on quantifications of virus in specific organs.

WOLF, K., R. L. HERMAN, AND C. P. CARLSON. 1972. Fish viruses: histopathologic changes associated with experimental channel catfish virus disease. J. Fish. Res. Bd. Canada 29: 149–150.

Nous avons fait un examen histologique d'alevins atteints expérimentalement de la maladie à virus de la barbue (CCVD). L'infection cause des hémorragies et des nécroses, les organes cibles étant le rein, le foie, le tractus alimentaire et le muscle squelettique. Ces résultats concordent avec les symptômes de la maladie et les données déjà publiées sur la quantification des virus dans des organes particuliers.

Received October 4, 1971

CHANNEL catfish virus disease (CCVD) is an acute hemorrhagic infection which typically occurs during summer and causes high mortality among young channel catfish (*Ictalurus punctatus*).

CCVD was first reported by Fijan (1968). In a subsequent publication, Fijan et al. (1970) described behavior and symptoms of infected fish, gave details of virus isolation, and demonstrated the etiology. They also described some characteristics of the virus and its effects upon culture grown cells. Wolf and Darlington (1971) described a method of plaque assay, additional virus characteristics, and the sequence of in vitro changes as seen by light and electron microscopy. Their work showed CCV to have the essential properties of a herpesvirus. Plumb (1971) used experimental infection to study the tissue distribution of CCV during its replication in the normal host.

The histopathologic effects of CCVD have not been reported; our purpose was to determine these effects.

Material and Methods

On the basis of health history, young channel catfish (6 month, 6.5–8 cm TL, 3–5 g) from the Fish Farming Experimental Station, Stuttgart, Arkansas, were free of virus. Three were killed for virological examination. Skeletal muscle and visceral organs were homogenized, filtered, and inoculated onto 150 cm^2 of susceptible cells. No evidence of virus was found. Under experimental conditions, preliminary trials showed that neither repeated feeding nor hour-long exposure to virus at 1×10^5 plaque forming units (PFU) per milliliter caused disease. Accordingly, intramuscular injection of about 5×10^5 PFU was used to infect the fish. During the incubation period, the fish were held in aquaria in aerated water at 30 C.

Auburn strain channel catfish virus (CCV) used for this work was obtained from Dr Nikola N. Fijan.[2] Stock virus was grown from a clone[3] that was obtained by harvesting a single well-isolated plaque.

The virus clone was grown in BB cells, the brown bullhead (*Ictalurus nebulosus*) line established by Cerini and Malsberger. The sixth passage of cloned virus was used for our work.

[1]Present address (R.L.H.): Owens-Illinois, Castalia Farms, Castalia, Ohio 44824, USA.

[2]Zavod Za Biologiju I Patologiju Riba I Pčela, Veterinarski Fakultet Sveucilišta, Zagreb, Yugoslavia.

[3]American Type Culture Collection VR 665.

Printed in Canada (J2316)

HISTOLOGICAL TECHNIQUE

Moribund fish showing behavior changes and other symptoms of CCVD were fixed in Bouin's solution then stored in 65% ethanol. Paraffin sections were cut at 5 or 7 μm and stained with hematoxylin and eosin.

Results

Twelve fish, which were in the terminal stage of the disease within 48–72 hr postinoculation, were processed for histologic examination. CCV infection resulted in a hemorrhagic disease condition with systemic edema and marked necrosis in kidneys, liver, and digestive tract. Renal hematopoietic tissue was generally edematous and sections invariably showed extensive areas of necrosis, advanced in some to the point of dissolution (Fig. 1). Numerous macrophages occurred in the kidneys. Livers showed regional edema and necrosis (Fig. 2). Submucosa of the digestive tract was edematous and mucosa often separated and sloughed into the lumen (Fig. 3). There were focal areas of macrophage concentration. Skeletal muscle showed multiple focal hemorrhage; necrosis was present but usually a separate feature (Fig. 4). Other tissues were indistinguishable from the controls.

Discussion

Channel catfish virus infection results in a rapid hemorrhagic and necrotic disease condition. The kidneys, liver, and gastrointestinal tract are the organs most severely affected. Our findings of extensive hemorrhages and evidence of edema agree with the gross symptoms reported by Fijan et al. (1970).

Histopathologic changes were most severe in the kidneys. In descending order, the gastrointestinal tract, liver, and skeletal muscle were also affected. The sequence corresponds almost exactly with tissue levels of virus found in victims of channel catfish virus disease (Plumb 1971). The brains of infected fish were no different than those of control animals. Plumb found a low level of virus in victims' brains at 96 hr but not at 70 hr. The lack of brain pathology may be due to the fact that our specimens had an acute infection and were moribund within 48–72 hr.

Although the etiologic agents have different nucleic acids and belong to different major groups of viruses, the histopathology of CCVD is generally like that of epizootic infectious hematopoietic necrosis, which is an acute disease of young North American salmonids. A notable exception is the lack of pathology in catfish pancreatic tissue. In contrast, all salmonid viruses produce pancreatic necrosis (Yasutake 1970).

When summer epizootics occur among young channel catfish, victims should be examined carefully for a bacterial or parasitic cause. In the absence of microscopic pathogens and if symptoms are those described for channel catfish virus disease, findings of the foregoing histopathology may be considered further presumptive evidence of the infection. For positive or complete diagnoses, the virus must be isolated and identified.

FIJAN, N. 1968. Progress report on acute mortality of channel catfish fingerlings caused by a virus. Bull. Off. Int. Epizoot. 69: 1167–1168.

FIJAN, N. N., T. L. WELLBORN, JR., AND JOHN P. NAFTEL. 1970. An acute viral disease of channel catfish. U.S. Bur. Sport Fish. Wildl. Tech. Pap. 43: 11 p.

PLUMB, J. A. 1971. Tissue distribution of channel catfish virus. J. Wildl. Dis. 7: 213–216.

WOLF, K., AND R. W. DARLINGTON. 1971. Channel catfish virus: a new herpesvirus of ictalurid fish. J. Virol. 8: 525–533.

YASUTAKE, W. T. 1970. Comparative histopathology of epizootic salmonid virus diseases, p. 341–350. *In* S. F. Snieszko [ed.] A symposium on diseases of fishes and shellfishes. Amer. Fish. Soc. Spec. Publ. 5, Washington, D. C.

(Fig. 1–4 on facing pages)

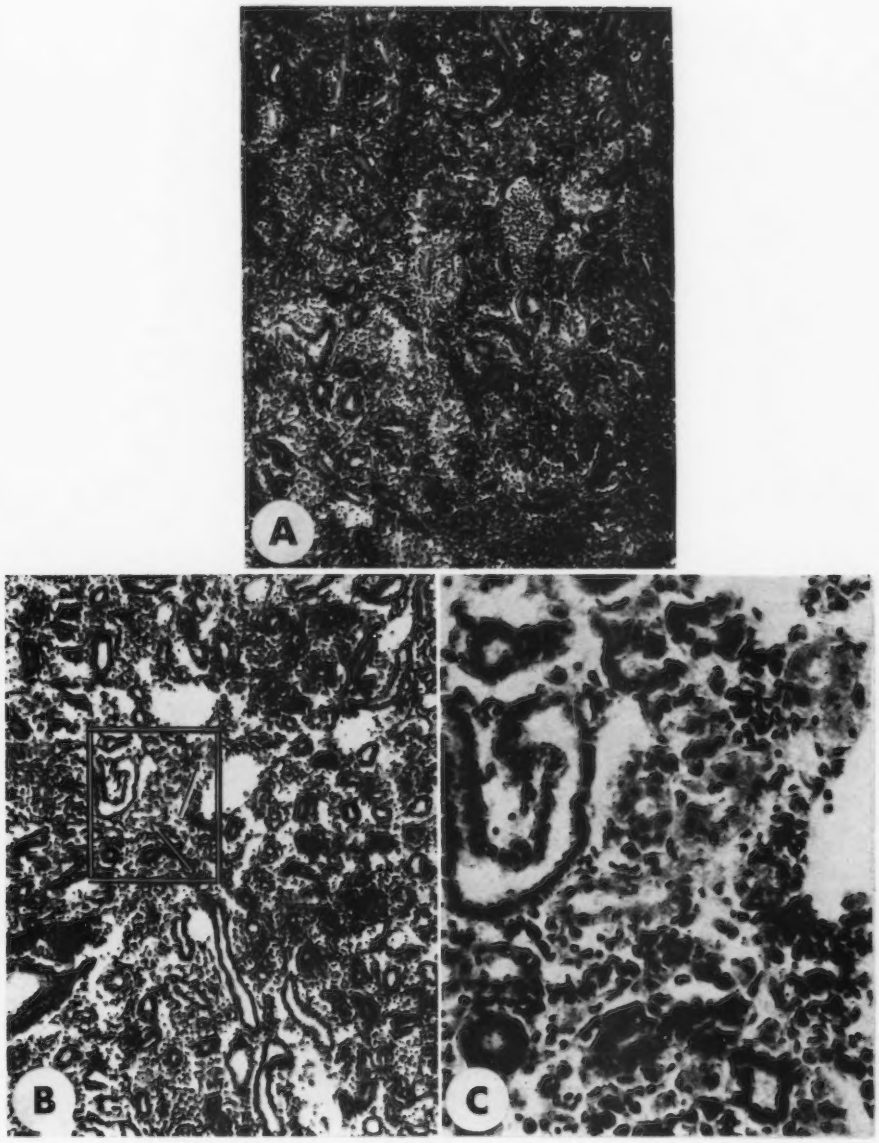

FIG. 1. Channel catfish kidneys. A, Control. ×75; B, Channel catfish virus infected showing edema. Arrows mark necrotic tubules. ×75; C, Inset from B showing details of necrosis. ×300.

FIG. 2. (*Top*) Liver pathology in CCV infected catfish. Edema and necrosis are prevalent throughout the center and right. A margin of nearly unaltered hepatic tissue is present on the left. ×502.
FIG. 3. (*Center*) Section of stomach of CCV infected catfish showing edema and mucosal sloughing. ×34.
FIG. 4. (*Bottom*) Focal hemorrhage in skeletal muscle of CVC-infected catfish. ×66.

Observations on the Migration of Sockeye Salmon Fry (*Oncorhynchus nerka*) in the Lower Babine River[1]

W. Craig Clarke[2] and H. D. Smith

Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

Clarke, W. C., and H. D. Smith. 1972. Observations on the migration of sockeye salmon fry (*Oncorhynchus nerka*) in the Lower Babine River. J. Fish. Res. Bd. Canada 29: 151–159.

No distinct length, weight, or behavioral differences associated with place of capture in the river were observed, indicating that all fry are susceptible to downstream displacement. A minimum of 7.5 million (18%) of the fry produced passed through a counting fence below the spawning grounds. Others reached quiet waters inshore, where they progressively developed behavioral characteristics that enabled them to ascend the river and reach lake nursery areas above. Two million fry ascended an improvised ladder spanning an area of turbulence at the base of the fence. Construction of leads and baffles at strategic places below the fence could help fry reach shore sooner and increase numbers reaching the lake.

Clarke, W. C., and H. D. Smith. 1972. Observations on the migration of sockeye salmon fry (*Oncorhynchus nerka*) in the Lower Babine River. J. Fish. Res. Bd. Canada 29: 151–159.

Aucune relation bien définie n'a été observée entre la longueur, le poids et le comportement et l'endroit de capture dans la rivière, ce qui indique que tous les alevins sont susceptibles de descendre le courant. Un minimum de 7.5 millions (18%) d'alevins sont passés par le barrage de comptage en aval des lieux de ponte. Les autres se sont réfugiés dans les eaux tranquilles à proximité du rivage, où ils ont progressivement acquis les caractéristiques de comportement qui leur a permis de remonter la rivière et d'atteindre les aires d'alevinage dans le lac en amont. Deux millions d'alevins ont franchi une passe de fortune installée sur un secteur turbulent, près de la barrière de comptage. La construction de canaux d'amenée et de déflecteurs aux endroits stratégiques en aval de la barrière aiderait les alevins à atteindre le rivage plus tôt et permettrait à un plus grand nombre d'atteindre le lac.

Received March 11, 1971

Anadromous sockeye salmon (*Oncorhynchus nerka*) characteristically spawn in areas where the resultant fry can enter a lake. Usually these areas are in inlet streams or at favorable sites along the beaches and on the bottom of the lake. In the Lower Babine River (Fig. 1), eggs are spawned in the outlet stream and fry must swim upstream to reach the nursery area.

Upstream migration probably requires a pattern of responses to such stimuli as current and light intensity, different from that which produces downstream movement. Once in the nursery area, fry from inlet streams lose their negative phototactic response, school, and develop a positive rheotactic response (Hartman et al. 1962). However, fry in outlet streams must undergo these changes much earlier or they may be carried into regions unfavorable for survival.

Unlike the phenomenon of downstream fry movement[3], upstream migration of sockeye salmon fry was not described in detail until McCart (1967) studied their behavior and ecology in the Babine River. Brannon (1967) and Raleigh (1967) added information from the Chilco River of British Columbia and the Karluk River of Kodiak Island, Alaska.

Our objectives were to (1) estimate numbers of fry passing downstream through a salmon counting

[1]Parts of this paper are based on a thesis submitted by W.C.C. in partial fulfillment of the requirements for the degree of Bachelor of Science from University of British Columbia.

[2]Present address: Department of Zoology, University of California, Berkeley, California 94720, USA.

[3]It is unclear when these fry are actively migrating or simply being carried by the current. We shall refer to all movement away from the lake simply as "movement."

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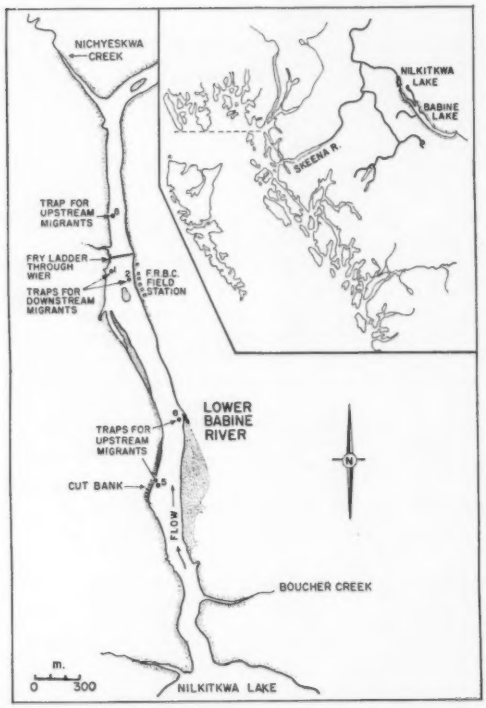

FIG. 1. Lower Babine River below Nilkitkwa Lake, B. C., showing location of traps for capturing sockeye fry.

fence on the Lower Babine River, (2) identify behavioral mechanisms by which these fry might avoid downstream displacement, and (3) examine ways in which their upstream return might be enhanced.

Description of Study Area

Since 1946, the Fisheries Research Board of Canada has maintained a salmon counting fence on the Lower Babine River about 1.6 km downstream from Nilkitkwa Lake (Fig. 1). The section of the river between the lake and fence supports most of the sockeye salmon spawners in the Lower Babine River. Over the past 22 years these have averaged 80,000 or 15% of the annual fence count of 4- and 5-year-old fish. Large numbers of sockeye fry produced in this section are transported below the fence and are unable to swim back upstream. A surface velocity of 2–3 m/sec over the fence and heavy turbulence below it present a total barrier to fry.

About 600 m below the fence, Nichyeskwa Creek enters the river from the west. It is about 30 m wide and its high discharge in the spring is also believed to block the return of any fry swept beyond it.

The river banks adjacent to the spawning area are generally low and steep and from 60 to 130 m apart. Fallen logs, overhanging vegetation, and patches of grass are frequently submerged in late May and June and produce some slack water areas near shore. Average surface flow is less than 31 cm/sec along the banks, but in midstream it is about 122 cm/sec.

Two small streams enter near the lake — Boucher Creek on the east, and an unnamed stream on the west bank. An island 50 m long is located near midstream opposite the camp.

Materials and Methods

Physical measurements and operation of traps — River water levels were read daily from a staff gauge in front of the field station. A three-pen Taylor thermograph provided a continuous record of temperatures in the air, the main flow of the river, and a grassy backwater below the cutbank where large numbers of fry accumulated. A Gurly Pygmy meter was used to measure water velocity at trap locations along the banks. Light intensity, during trough experiments and evening netting sessions on the fence, was measured with a Photovolt Model 210 photometer placed on a horizontal surface, about 150 cm above the water.

Traps, termed "upstream" or "downstream" according to direction captured fry were moving, were situated at five locations along the banks (see Fig. 1). Upstream traps (no. 5, 6, and 8) were rectangular wooden frames covered on the sides with plastic screening, and on the top, bottom, and upstream ends with plywood. They fished the entire depth near shore. Openings were 31 cm deep and 62 cm wide; a lead of screening was placed between each trap and the bank. V-shaped entrances prevented fry from escaping unless the traps became very crowded. Downstream traps (no. 1 and 2) were 3 m long cone-shaped nets with 31 cm openings, suspended between stakes about 1 m from shore such that the current velocity on the offshore side was about 31 cm/sec. Leads were extended from the traps to shore, and traps were adjusted periodically to fish the top 30 cm of water. Net "C", one of four sampling nets on the fence, was another source of downstream fry.

Estimate of number passing through the counting fence — Because large numbers of fry were involved and high, sometimes unmanageable water levels prevailed, a complete population census was not attempted. Rather, estimates were made by measuring diel movement and spatial distribution of fry across the fence, and on the basis of these, a series of index catches were expanded to obtain estimates of 24-hr totals. Estimates for nights without fishing effort were obtained by interpolating between preceding and following estimates. All estimates were summed over the period of the run to give the season's total.

Trough experiments — A plywood trough, 246 × 46 × 61 cm deep, was anchored in the river to provide 41 cm of water inside. Fine mesh screening in moveable gates at each end restricted current velocity to 12 cm/sec. vations in a horizontal plane. The upstream 46 cm of Two 31 × 62-cm plexiglass windows permitted obser-

the trough floor was covered with rocks about 8 cm in diameter.

The experimental procedure was a modification of that described by McDonald (1960). Fry from above and below the fence were tested separately on consecutive nights. They were captured in dipnets 1–3 hr before sunset and immediately placed in the middle of the trough. Downstream movement was expressed as the number of individuals moving into the lower third of the trough during consecutive 15-min intervals. Observations were begun at dusk with an infrared viewer and a light source powered from a 6-v storage battery.

Orientation — Activity and alignment of fry moving downstream at the surface in bright daylight was observed from the fence or a boat anchored at various distances from shore (locations described in Table 1). Fry were recorded as (1) drifting, (2) swimming toward west shore, (3) swimming toward east shore, (4) swimming against current, or (5) swimming with current.

Size and development of fry migrating upstream were compared with those moving downstream May 30, June 9–12, and June 19. In each sampling period 25 fish were obtained from traps 1, 5, 8, and C. These were anesthetized with tricaine methanesulfonate (M.S. 222; Sandoz) and blotted with paper towels. Each was weighed ± 0.01 g on an Ohaus Dial-o-gram balance, and standard length was recorded to the nearest 0.5 mm by placing it on a sheet of calibrated paper. Individual fry were classified according to the amount of visible yolk sac on a 6-stage developmental scale encompassing the alevin stage to complete fusion of the midventral wall (Fig. 2).

Fry ladder — A ladder 18 m × 15 cm was built through the fence on the west bank to permit fry, trapped below the fence, to continue their upstream migration. Alternating baffles at 23-cm intervals extended inward 11 cm from the sides and provided resting places. The ends of the ladder were raised or lowered as required to keep it full of water as river levels fluctuated. Estimates of fry ascending the ladder were based upon the time required for 100 to exit at the top. These measurements were repeated hourly for 24 consecutive hours on 3 days, initially to determine diel periodicity of movement. Thereafter, counts were made twice daily to estimate the daily rate of passage.

Statistical analysis — Most fry orientation data were analyzed by chi-square; the Kolmogorov-Smirnov one-sample test was applied to one sample that was too small for the chi-square procedure (Siegel 1956). Length, weight, and yolk size data were tested for significant differences attributable to sampling date or location by two-way analysis of variance. The studentized range test (Snedecor 1965) was then used to determine sampling dates or locations that were significantly different.

Results

Physical measurements — Water level in front of the field station increased 54 cm between May 8 and June 17. Water temperature in the main current at the cutbank increased from 5.5 to 12.5 C between May 7 and June 25, but varied no more than 1 C in any 24-hr period (Fig. 3). A period of high turbidity prevailed in the river for several days beginning June 5.

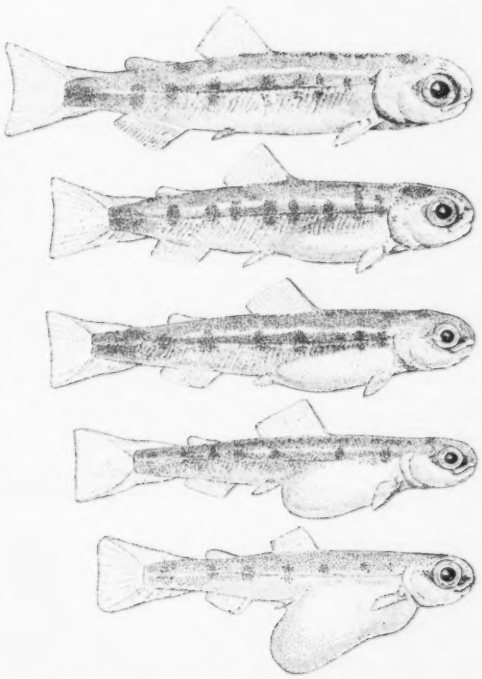

FIG. 2. Arbitrary stages in absorption of yolk sac. The largest yolk sac shown at the bottom is stage 1. Stage 6 (not shown) represents complete fusion of the midventral wall with no yolk visible externally.

Trap catches — On May 22, the 24-hr catch at trap 5 at the cutbank was 1200 fry. Catches increased to 1600 on May 25, 4000 on May 27, and by June 1 had reached 250,000 or 62.5 times that of May 27. Meanwhile at trap 6 across the river, the June 1 catch was 3.8 times and the June 2 catch 164 times the May 28 catch of 59 fry. Peak migration appeared to occur about this time, but the relative size of catches became doubtful thereafter as rapidly rising water necessitated frequent trap adjustments.

Catches in trap 5 were recorded hourly from 1000 to 2200 hr June 1 and during the 24-hr period commencing 0900 hr June 9. June 1 weather was clear and the migration peaked between 1300 and 1400 hr whereas, on June 9 migration was maximal from 0900 to 1000 hr in bright sunlight, but later declined as clouds gathered and rain fell (Fig. 4). The offshore

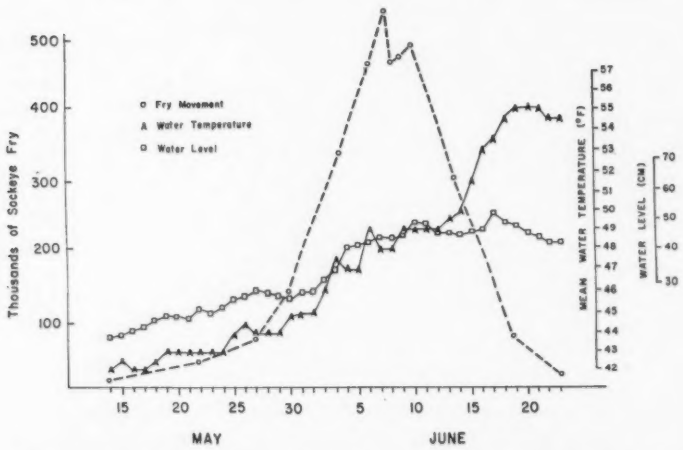

FIG. 3. Seasonal timing of the downstream movement of sockeye fry through the Babine River counting fence in 1966.

water temperature increased from 7.7 to 8.5 C during the fishing period on June 1, but varied less than 0.1 C during June 9–10. Thus, catches could not be related to water temperature.

On June 14, a cloudless night, net C was fished for 5-min periods alternating with 5-min periods of no fishing, and the catches and light intensity were recorded. Highest catches were related to rapidly falling light intensity:

Time	*Catch (fry)*	*Light intensity (ft-c)*
2155	No fishing	.93
2200–2205	24	No measurement
2210–2215	19	.26
2220–2225	31	.08
2230–2235	46	.04
2240–2245	23	.01
2250–2255	20	.008

A similar pattern of increased catch with falling light intensity occurred May 30, but it was noted that movement in midstream was earlier and more prolonged than at trap 1 on the bank (Fig. 5).

Estimate of numbers through the fence — About 7.5-million fry passed through the fence between 2000 and 0300 hr during May 14–June 23. (This may be a substantial underestimate of the season total, as will be discussed below.) Seasonal timing is indicated in Fig. 3. Numbers were low during May, rose sharply in the first week of June, leveled off at about 500,000 in each of several consecutive 24-hr periods, then subsided rapidly. At least 80% of the movement appears to have occurred during the first two weeks of June.

Numbers passing through the fence are most significant when expressed as a percent of the total production in the Lower River in 1966. Both egg deposition and egg–fry survival estimates are required for this calculation. The former are available from routine annual measurements of the Lower River population, but no measures of egg–fry survival have been obtained. Egg–fry survival of the 1965 brood in Fulton River and Pinkut Creek, tributaries to Babine Lake, were 12.5 and 13.5% respectively (R. Kearns personal communication). Survival in the excellent Lower River spawning grounds would usually exceed that of the tributary streams, so we have used 15% in the following:

1956 spawning escapement	% ♀	*Eggs/♀*	*Potential egg deposition (millions)*
176,000	55.0	2800	271.04

Est. egg–fry survival (%)	*Est. fry produced (millions)*	*Proportion passing fence (%)*
15.0	40.656	18.4

Escapements on the river are measured annually by tag and recovery procedures, sex ratio is assessed for the entire run as it passes the fence, and the 1965 estimate is applied here. Fecundity is based upon female length–egg content relation established over

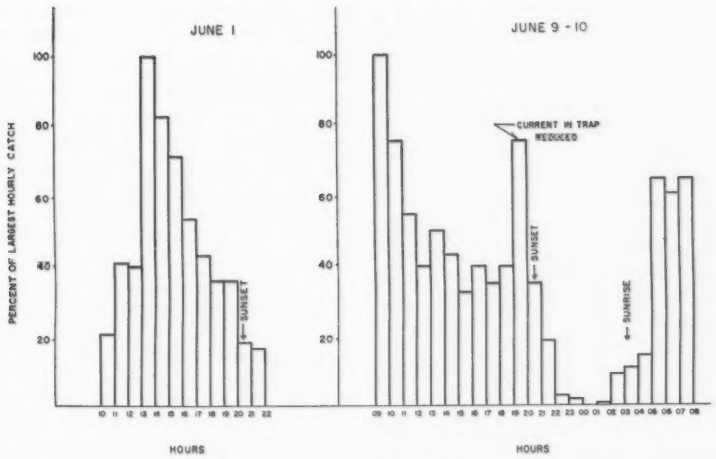

FIG. 4. Diel periodicity of upstream migration of fry at the Lower Babine River cutbank, June 1 and June 9, 1966.

many years. These figures indicate that more than 18% of the fry produced in the Lower Babine River in 1966 passed through the counting fence.

Observations near the banks — Behavior changed noticeably as the season progressed. At dusk in early May, individual fry immediately above the fence were oriented at a considerable angle to the current and swimming downstream. This eventually brought them to quiet water inshore. After dark, small concentrations could be seen by flashlight around the roots and under leaves of inundated clumps of grass. Others were found in loose materials on the bottom close to the banks during daylight.

About May 20 the first schools were seen holding along the banks above the fence. These increased rapidly for about a week then declined. A sharp increase in catches in all traps followed — perhaps indicating that fry were beginning to migrate toward the lake. Water temperature and level had risen rapidly (Fig. 3).

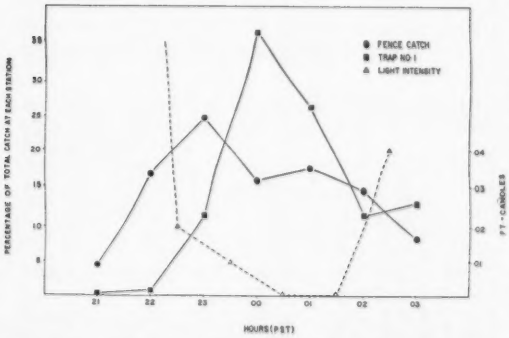

FIG. 5. Diel periodicity of downstream fry catches on the Babine River counting fence and at trap 1 on the shore, May 30, 1966.

In the first week of June there was a steady increase in numbers along the banks, and by mid-June fry were seen at almost any hour in places where high velocities offshore forced them into the shallows. In such areas, hundreds were at times swept onto gravel banks by waves from passing boats. By June 20, numbers had declined to isolated schools of about 200 fry. By mid-July the only fry seen were in a large pool at the lake outlet.

Underwater observations — Fry were readily seen moving upstream close to the river banks. In fast water they tended to swim independently, but were inclined to accumulate in quiet zones behind rocks and snags and form narrow bands close to the banks. None were seen from the west bank between the fence and Nichyeskwa Creek where surface velocities exceeded the maximum swimming speed of the fry, but at about 1-m depth they were moving rapidly upstream in a narrow column. These were nearly in contact with undercut sections of bank and took advantage of any projections that caused reduction in water velocity. At times they darted in rapid succession from one projection to another.

Fry also crossed the mouths of sloughs and streams while remaining oriented. At swift Boucher Creek, schools sounded and crossed close to the stream bed. Individual fry attempting to cross at the surface adjacent to the west bank tributary were swept back.

TABLE 1. Numbers and orientation of fry in Lower Babine River, June 8 and 13, 1966[a] (*Significant at 0.01 level, ** significant at 0.05 level.)

	Location							
	150 *m* above fence June 8		90 *m* above fence June 13 Distance from E bank		On fence June 13 Distance from E bank		On fence June 13 Distance from W bank	
	6 m from W bank	9 m from island (East side)	6 *m*	12 *m*	9 *m*	37 *m*	37 *m*	23 *m*
Behavior	0915–0940 hr	0845–0915 hr	1010–1020 hr	1020–1045 hr	1945–2000 hr	1930–1945 hr	1900–1915 hr	1917–1930 hr
Drifting	0	0	0	1	0	0	0	0
Swimming to W bank	12	8	4	7	4	8	13	9
Swimming to E bank	0	4	13	19	17	10	10	2
Swimming against current	1	1	0	6	2	4	18	0
Swimming downstream	9	0	3	13	6	5	13	9
χ^2 calculated	19.1**	0.423*[b]	18.8**	9.7**	18.6**	3.4	2.5	13.2**
Tabulated ($P = 0.05$)	7.8	0.361	7.8	7.8	7.8	7.8	7.8	7.8

[a]Significance tests apply only to categories of actively swimming fry.
[b]Kolmogorov-Smirnov test.

Later, during a period of low discharge, they crossed at the surface.

Trough experiments — When placed in the middle of the trough, most fry congregated in the upper end. As light intensity approached .01 ft-c, they continued to swim against the current, but gradually lost ground until just ahead of the downstream end. Proportions of fry from above and below the fence that lost position did not differ significantly ($P > 0.1$). Downstream movement was probably not induced by fatigue since all fry returned to the upper third of the trough when left until daylight.

When a light was shone into the trough after dark, fry in the lower, smooth-bottomed portion maintained position, but those holding over the stones in the upper portion immediately sought cover among them, but emerged again as soon as the light was extinguished.

Orientation — Within 12 m of the east bank and 23 m of the west bank, most fry were oriented toward the nearest bank (Table 1). However, orientation of fry more than 23 m from shore did not depart significantly from random. The chi-square test was applied only to the categories of actively swimming individuals because no assumptions could be made concerning the expected frequency of drifting fry. Most fry oriented toward the banks were moving diagonally downstream. At all locations the water velocity was sufficient that fry swimming directly against the current were carried backward.

Measurements of size and stage of development — Mean length and weights of fry in four traps in three sampling periods are shown in Table 2. There were no significant differences due to date or sampling location ($P > 0.1$). However, weight differed significantly with sampling date ($P < 0.05$). The studentized range test showed a significant decline from the mean of .1751 g on May 30 to .1528 g on June 19 ($P = .05$; D = .02219). There was no significant weight difference due to sampling location.

TABLE 2. Mean length (mm) and weight (g) of sockeye fry at four locations in three sampling periods on Lower Babine River, 1966.

	Sampling period					
	May 30		June 9–12		June 19	
Source	Length	Wt	Length	Wt	Length	Wt
Trap 8	27.32	.1816	28.02	.1644	27.78	.1644
Trap 5	28.22	.1760	27.50	.1664	27.76	.1460
Trap 1	27.74	.1700	27.94	.1876	27.76	.1432
Net "C"	27.64	.1728	27.70	.1672	27.22	.1576

Analysis of measures of visible yolk showed highly significant differences between upstream and downstream migrants associated with both date and sampling location ($P < 0.005$). Larger numbers of early-stage fry moving downstream may mean that they had recently emerged and lost position during darkness. Of six possible comparisons of means by the range test, three revealed significant differences ($P < .05$). These were between downstream migrants at the fence (net C) and upstream migrants below the fence (trap 8); between downstream migrants in trap 1 and upstream migrants in trap 8; and between downstream migrants at net C and upstream migrants in trap 5 at the cutbank. Yolk-sac absorption advanced throughout the season in both upstream and downstream fish (Fig. 6).

The fry ladder — During June 7–27, fry ascended at a daily rate of about 100/min during 20 hr of light and about 25/min during 4 hr of darkness. We estimate that more than 2 million ascended during 16–½ days of continual, and 4 days of intermittent operation. This was probably the greatest rate possible through this ladder as the lower sections were often so choked with fish that fry on the surface were lifted out of the water by those struggling beneath them.

Current velocities in the ladder varied from 12 to 48 cm/sec but averaged about 31 cm/sec. A relatively high velocity (76 cm/sec) prevailed at the narrow slit where fish entered the ladder. This appeared to approximate the maximum swimming speed of the fry.

Discussion

An estimated 7.5 million fry passed through the fence between 2000 and 0200 hr, May 14–June 23. However, while past records indicate that most of the Lower Babine River fry move downstream dur-

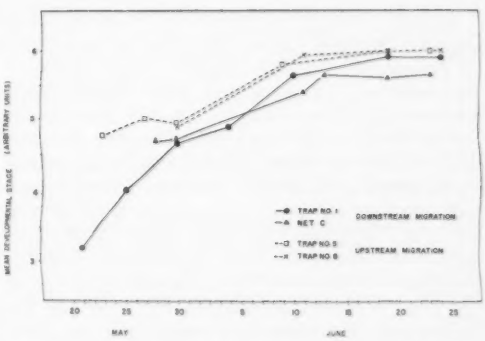

FIG. 6. Developmental stage at four trapping sites during May and June (see Fig. 5 for arbitrary scale of yolk absorption).

ing darkness (McCart 1967, fig. 10), many were seen moving at the surface in bright sunlight beginning June 7, 1966, and during a period of high turbidity for several days thereafter. Our observations are inadequate to show the size of this migration clearly, but two of four index nets operated from the fence and emptied hourly (0930–2000 hr) caught an hourly average of 23% (range 12–48%) of the corresponding 2200–2300-hr catch. Daylight catches expanded in the usual way indicated a movement in excess of 250,000 fry outside the regular nocturnal 5-hr fishing period. Our seasonal estimate based upon nocturnal catches alone is therefore considered to be a substantial underestimate.

If an extra 5.5 million fry (total through fence less return via ladder) had reached the lake and realized 0.8% survival to adult stage (Foerster 1968, p. 371, for an "average" survival rate) rather than being lost entirely, 44,000 more adults might have returned. Thus, the adult potential of the 1966 fry passing through the fence was substantial. Even larger numbers would be expected in years of extreme high water.

Lack of evidence demonstrating distinct size or behavioral differences between fry captured above and below the fence suggests that all fry are necessarily displaced a short distance downstream after emergence, but some are swept through the fence before they reach shore. However, there is strong evidence for some different patterns of fry behavior in time and space suggesting that their survival depends upon specific responses to the environment.

As there is no evidence from scale readings or elsewhere that Babine Lake sockeye can complete the freshwater phase of their life cycle without a period of lake residence, it appears that those which respond poorly do not reascend from below the fence and perish. Response to light seems particularly important.

Most of the nightly movement through the fence occurred between 2100 and 0200 hr daily. Ali (1959) suggests that such sharply peaked pattern of fry migration may be due to a state of partial night blindness. He found that when the light intensity fell below the cone thresholds (1.0–0.1 ft-c), the eyes of fry started the process of dark adaptation, which is completed in 35–40 min. However, in nature, the light intensity can drop more rapidly than the fish can adapt. This leaves the fry in a semi-light adapted state and they are displaced downstream. Reduced migration later in the evening might be explained by the fact that when dark adaptation is complete, the fry are able to perceive large objects and use them as reference points.

Previous work indicated that downstream movement by sockeye fry from tributary streams is predominantly nocturnal (Hartman et al. 1962, 1967; McDonald 1960). However, outlet fry may inherit a different behavior response to light. Raleigh (1967) used an experimental trough to study the behavior of outlet and tributary sockeye fry from Karluk Lake, Alaska. Only 6% of the tributary, but 42.4% of the outlet fry, migrated in the trough during daytime.

It is also possible that daylight downstream movement accompanied usual nocturnal movement in 1966 in the Lower Babine River because of an increased silt load, as described for pink salmon fry by Coburn and McCart (1967). Either the silt itself, or the reduction in light penetration simulating periods of nighttime darkness, might trigger the movement. If, as suggested by Brannon (1967), sockeye fry orient upstream more positively in lake than in stream water, increased discharge from tributaries could induce additional downstream displacement during periods of heavy runoff, even though the silt load was light.

The relative advantages of daylight and nocturnal downstream movement in the Lower Babine River are unclear. If the daytime movement is aberrant, it seems likely that this behavior would be deleterious to the fry.

The more sharply peaked downstream movement of fry along the banks, as compared with that on the fence, probably results from increased opportunity to maintain visual contact with the bottom during daylight and possibly during twilight periods. Trap avoidance would also reduce daytime catches along the banks, but probably had less influence on the fence catches because of the higher velocities.

The change in behavior, from hiding under banks during daylight in early May to moving upstream about a week later, implies that a progressive development of behavioral characteristics was taking place. Hoar (1958), discussing fry that had been out of the gravel a short time, states "Somewhat older fry show a change in reactions which seem to form the basis of an upstream migration. They hide less under stones ... remain exposed at higher light intensity ... and respond strongly to current even at higher temperatures ...." Both Hoar (1960) and McDonald (1960) note that a change in behavior from purely nocturnal emergence to voluntary exposure at higher light intensities is essential to schooling and upstream migration. It is also clear that strong photonegativity during late alevinage reduces the danger of emergence before the fish is capable of holding against the current.

In the experimental trough, as the light intensity approached 0.01 ft-c, fry were displaced individually while remaining positively rheotactic as reported by McDonald (1960) and did not turn and swim

with the current as described by Hoar (1958). Fry used in this study were more developed than those used by Hoar, and, unlike his fry, ours remained exposed during daylight hours. These facts may account for the discrepancy. Furthermore, Hoar's fry from inlet populations moved downstream to their nursery areas.

The observed tendency of fry to swim across the current is thought to be a response to the shore rather than a rheotactic response. Within 23 m of either bank, a significant proportion of fry observed at the surface were swimming toward the nearest shore, while those more than 23 m from the banks were oriented randomly. In streams with U-shaped bottom profiles fry might reach the banks by swimming toward shallower water. In Babine River, depth does not change appreciably over the greater width of the river, so can be of little assistance. Specific stimuli have not been identified, but apparently are important in orienting fry toward shore soon after emergence.

Light, but not temperature, appears important in stimulating upstream movement. For instance, daily rhythm of upstream migration at the cutbank could not be related to fluctuations in the temperature of the river, but hourly fry counts on two separate days support McCart's (1967) suggestion that light intensity controls the daily initiation and termination of upstream movement. On a clear sunny day, peak fry movement took place in early afternoon, while on a second day, peak movement occurred in midmorning under sunny skies but decreased steadily in the afternoon when cloudy skies and rain prevailed (see Fig. 4). The relative absence of upstream movement during hours of darkness indicates a need for visual contact with the river bottom.

These observations suggest that sockeye fry in the Lower Babine River depend substantially upon positive and changing responses to the environment with increasing development. Survival rates might therefore be improved if environmental factors such as flow or turbidity could be regulated, or if spawning adults could be kept from locations unfavorable for fry survival, e.g., below the counting fence, particularly in midstream where orientation to the banks might be difficult or impossible. (Closing the adult fence to downstream migration of spawners might be a positive step). Further consideration of these and other possible actions is required. Meanwhile, some gains can likely be made by installing leads, either floating or attached to piling, downstream and outward from the banks below the counting fence to help fry reach shore sooner. Baffles or other objects to reduce velocities, or floating sections of ladder, as described above, to bridge points of difficult upstream passage could be helpful. Experiments are needed to help design and deploy such devices.

Acknowledgments

The authors are grateful for the constructive criticism of the manuscript by Mr J. McDonald and Dr R. R. Parker, and for the final reading by Mr S. J. Westrheim. Mr J. Martell provided valuable technical assistance in the field.

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Biology of Rock Crab (*Cancer irroratus*) in Northumberland Strait

D. J. SCARRATT AND ROBERT LOWE[1]

Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

SCARRATT, D. J., AND R. LOWE. 1972. Biology of rock crab (*Cancer irroratus*) in Northumberland Strait. J. Fish. Res. Bd. Canada 29: 161–166.

Divers hand-collected 342 rock crabs (*Cancer irroratus*) ranging from 4.2 mm carapace width to 97 mm (females) and 127 mm (males). The sex ratio (1.37:1) was biased in favour of males. Of 2929 crabs taken in commercial lobster fishing gear, 92% were above the minimum commercial size of 89 mm, and of these 99.1% were male. Smallest size at maturity was 60 mm for females and 69 mm for males. Breeding occurred in late summer and fall. Larvae were present in surface waters from June to September. Prey of crabs >25 mm consisted principally of polychaetes, mussels, starfish, and sea urchins. Crabs less than about 65 mm inhabit rocky areas; larger crabs move out onto sand and mud. The fishable population is probably not in significant competition with lobsters for food or space.

SCARRATT, D. J., AND R. LOWE. 1972. Biology of rock crab (*Cancer irroratus*) in Northumberland Strait. J. Fish. Res. Bd. Canada 29: 161–166.

La largeur de la carapace de 342 crabes-tourteaux (*Cancer irroratus*) capturés à la main par des plongeurs varie de 4.2 mm à 97 mm (femelles) et 127 mm (mâles). La proportion des sexes est de 1.37:1 en faveur des mâles. Sur un total de 2929 crabes capturés dans les casiers à homard des pêcheurs, 92% ont une taille supérieure au minimum commercial de 89 mm (3½ pouces) et parmi ceux-ci, 99.1% sont des mâles. La plus petite largeur à maturité est de 60 mm pour les femelles et 69 mm pour les mâles. La reproduction a lieu en fin d'été et à l'automne. On trouve des larves dans les eaux de surface de juin à septembre. Les crabes de plus de 25 mm se nourrissent surtout de polychètes, moules, étoiles et oursins de mer. Les crabes de moins de 65 mm habitent des endroits rocheux; ceux plus gros fréquentent des fonds de sable et vase. Il n'y a probablement pas de concurrence alimentaire ni spatiale sérieuse entre la population exploitable de crabes et le homard.

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FOR some years a few fishermen in parts of Northumberland Strait, Gulf of St. Lawrence, have been landing and selling crabs (*Cancer irroratus*) which they caught while fishing for lobsters (*Homarus americanus*). Hitherto these crabs had been regarded as a nuisance and thrown overboard, or sometimes used as bait. Attempts to establish a separate fishery have been unsuccessful (Department of Fisheries 1964, 1966), and rock crabs remain a by-product of the lobster fishery. There is no legal size limit, but for practical purposes an effective lower limit of about 89 mm carapace width[2] is observed.

There is little published information on the life history or biology of *C. irroratus*. Jefferies (1966, 1967) described the ecological relation between *C. irroratus* and *C. borealis* in Narragansett Bay. Wilder (1966) described some aspects of the crab fishery, and Cornick and Stewart (1968) explored the possibility that *C. irroratus* was a carrier of *Gaffkya homari*, the blood disease pathogen of lobsters. The present paper is based on a study of crabs in Kouchibouguac Bay, N.B., designed to explore their biology, population structure, and ecological relation with lobsters.

Methods

Samples of crabs were hand-collected at 79 stations spaced 0.93 km apart, in a crescent-shaped area approximately 7 km long × 2 km wide located north of Richibucto, N.B. (Fig. 1), in depths between 4 and 18 m. Divers searched a 20.9-m² area of sea bed, temporarily surrounded by a nylon net (1 m high) fastened to a folding metal frame, and collected all crabs seen. The net was set at random in four separate places at each station. Each station was occupied once between June 6 and 30,

[1]Present address (R.L.): Harvard Medical School, Boston, Mass.

[2]Size of crabs refers to carapace width at its widest part.

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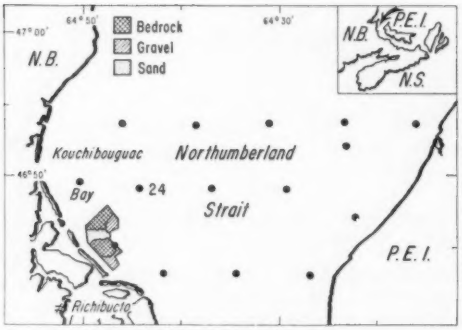

FIG. 1. Seventy-nine stations within the outlined area in Kouchibouguac Bay were sampled by divers. Sediment distribution is from Kranck (1967). Larval sampling stations are shown thus ●. Station 24 was used for collecting samples over 24-hr periods. Inset shows the location of the study area in eastern Canada.

1967, and 25 were sampled again between September 21 and October 5, 1967.

Crabs collected were brought to the surface and preserved immediately in a 5% solution of buffered formalin in sea water. Carapace width was measured to 0.1 mm with vernier calipers, and each crab weighed to 0.1 g. The carapace was removed and gonad development classified as undeveloped, developing, or mature or ripe. The ripe testis has a coiled appearance and is creamy in colour, while the developing testis is smaller and whiter. The ripe ovary has a reddish, granular appearance, and almost fills the upper part of the body cavity, while the developing ovary is smaller, smoother, and paler. Berried females (carrying external eggs) were identified. The stomachs of crabs >25 mm were excised, weighed, and the contents flushed into a petri dish for examination and identification under a binocular microscope. The empty stomach was weighed, and the weight of the contents obtained by subtraction. From this and its relative volume, an estimate was obtained of the weight of each prey item.

Data on crab larval abundance were obtained from a series of 30-min surface plankton hauls at 15 stations in Northumberland Strait (Fig. 1). The net, which was 3.7 m wide × 0.9 m deep, floated at the surface and filtered the upper layer (0.6 m). Towing speed was about 1 knot. Distance covered in each tow was therefore about 925 m.

The numbers and size distribution of crabs taken in commercial lobster fishing gear were recorded during annual surveys of the lobster fishery in 1955 and 1968.

Results and Discussion

NUMBERS, SIZE DISTRIBUTION, AND SEX RATIO

Divers' samples — Divers collected 210 crabs from 79 stations in June 1967, and 132 from 25 stations in September–October. Males ranged between 11–127 mm carapace width, and weighed up to 300 g. Females ranged between 14–97 mm, and weighed up to 140 g.

One crab, 4.2 mm, could not be sexed. Regressions of total weight against carapace width (based on the model $Y = aX^b$) for 126 nonberried females and 197 males were not significantly different ($t = 0.237$). The regression of total weight against carapace width for males and nonberried females combined was $\log_e Y = -9.083 + 3.060 \log_e X$. Berried females were heavier than nonberried females of similar carapace width ($\log_e Y = -8.086 + 2.886 \log_e X$) and carried up to 40 g of eggs. Male–female sex ratio was 119:91 (1.31:1) in spring, and 78:53 (1.47:1) in fall. These were not significantly different ($\chi^2 = 0.27$, $.25 < P < 0.5$). The sex ratio of the combined samples was significantly different from 1:1 at the 5% level ($\chi^2 = 4.14$). It is not possible to deduce whether more males hatch and settle, are easier for divers to find, or, having a larger maximum size, live longer than females.

Samples from commercial lobster traps — In 1955, 2049 crabs, caught at five localities in Northumberland Strait, were sexed and measured. As Table 1 shows, 89.9% were above 89 mm, and of these 98.8% were male. Of 880 crabs taken off Abrams Village and Miminegash, P.E.I., in 1968 (Table 1), 97.1% were above 89 mm and 99.7% of these were male. The largest crabs measured about 130 mm. Proportionally more small crabs were taken at Lower Cape Bald than elsewhere, but this may represent trap selectivity rather than a different population structure.

GROWTH

Carapace-width increments (in millimeters) at moulting, for four female crabs that were either observed to moult or were captured by divers together with the recently cast shell, were:

Pre-moult	15.8	62.0	64.5	64.5
Post-moult	20.5	76.1	80.9	80.9
Width increment (%)	29.8	22.8	25.4	25.4

The scarcity of female crabs larger than about 90 mm suggests a terminal moult. Only one crab >25 mm was taken in June. Crabs below this size in fall were probably young-of-the-year.

MATURITY AND BREEDING

In June, males with undeveloped gonads were up to 82 mm in size (Fig. 2). Males with developing gonads ranged from 50 to 100 mm, and ripe males from 69 mm upwards. In the fall sample, propor-

TABLE 1. Numbers of crabs, mean carapace width, percentage above 89.0 mm, and percentage above 89.0 mm that were male, in commercial lobster fishing traps.

Location	No. traps	No. crabs	Mean carapace width (*mm*)	% above 89.0 mm	% males above 89.0 mm
			1955		
Miminegash	1550	700	105.3	95.3	99.4
Cape Egmont	170	273	98.2	91.9	100.0
Egmont Bay	968	796	100.6	88.2	99.6
Summerside	220	105	110.7	97.1	98.0
Cape Bald	–	175	101.9	80.6	91.5
Total		2049		89.9	98.8
			1968		
Miminegash	2676	527	102.4	96.6	100.0
Abrams Village	75	353	106.0	98.0	99.4
Total	2751	880		97.1	99.7

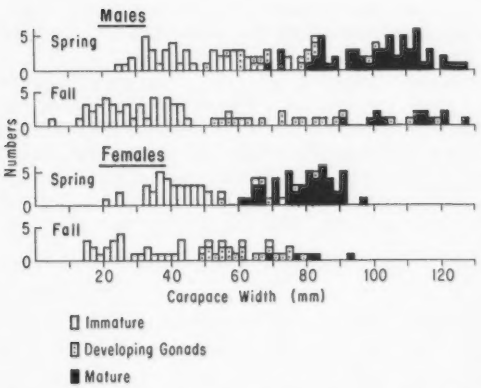

FIG. 2. Maturity and size distribution of crabs collected by divers.

tionally fewer males above 60 mm were ripe, and more were in the developing-gonad stage.

In June, the smallest ripe female measured 60 mm, and the smallest berried female, 65 mm. Seventeen of the 55 female crabs above 60 mm were berried, as opposed to none of the fall sample. Fewer of the fall sample had ripe gonads, and proportionally more were in the developing stage.

Paired male and female crabs in courtship have been seen by divers in Kouchibouguac Bay between July and October. The male invariably clasps a female 30–40 mm smaller across the carapace, sternum to sternum. He will withstand considerable harassment before abandoning her. Chidester (1911) described mating of the blue crab (*Callinectes sapidus*) and assumed that *Cancer irroratus* behaved similarly. The male *Callinectes sapidus* releases the female while she is moulting, and copulation takes place immediately afterwards. Similar behaviour is reported in all Cancridae for which mating behaviour has been observed, and is usually followed by a period of post-copulatory embrace, where the male crab is presumably protecting the soft-shelled female (Edwards 1966; Snow and Neilsen 1966; Hartnoll 1969). It is probably safe to assume that *Cancer irroratus* follows this pattern.

The period between copulation and egg laying is not known, nor the period between egg laying and hatching.

LARVAL ABUNDANCE AND DISTRIBUTION

Larvae of *C. irroratus* were present in surface waters between mid-June and mid-September. Larval abundance in 1962 was about eleven times that in 1963: an average of about 4100/30-min tow, as opposed to 370. Peak periods of larval abundance appear to be August and September in both years (Fig. 3), during the period when surface water temperatures are beginning to decline and bottom water temperatures are approaching their maximum. Relative abundance and survival rates of the different larval stages are not known. It seems likely that, as with the lobster (Scarratt 1964), there is considerable variation in crab larval abundance from year to year. Larvae were taken in varying numbers at all stations

fished, which implies the presence of some adults over the whole area.

Five series (one series in August 1962 and four in August 1965) of 30-min tows, taken at 2-hr intervals throughout a 24-hr period at station 24 (Fig. 1), yielded about 80,000 larvae. The 38 daylight hauls averaged about 1100 larvae each (range 0–5000), and 27 night-time hauls about 1400 each (range 0–9200).

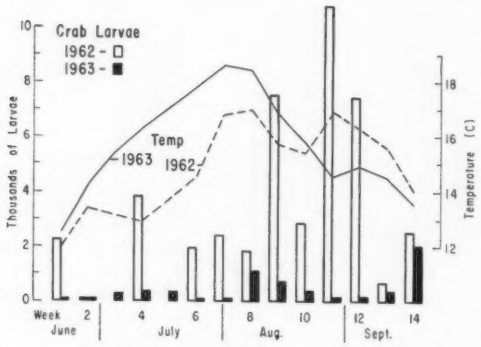

FIG. 3. Weekly mean catch/tow of crab larvae and surface water temperature in 1962 and 1963.

There is no clear evidence that crab larvae are more abundant at the surface at any particular time of the day or night, although the possibility that they make vertical diurnal migrations cannot be eliminated.

STOMACH CONTENTS

Stomach contents of 230 crabs (size range 25–127 mm) were frequently liquid, or consisted of a semi-digested amorphous mass, but prey could be distinguished in many (Table 2). Principal prey were polychaetes, particularly nereids and polynoids identifiable by persistent jaws or elytra (specific identification was not always possible), mussels (*Modiolus modiolus*), starfish (*Asterias vulgaris*), and sea urchins (*Strongylocentrotus droebachiensis*). Mollusc shell fragments and sand grains were taken in small quantities, and other species appeared irregularly. It appears that most food is taken alive. Approximately 30% of the crabs collected in June had empty stomachs, whereas all the September–October sample contained food. The proportion containing liquid or amorphous matter was higher in fall than in spring. This may indicate higher feeding and digestion rates in warm water. There was no evidence of cannibalism or of predation upon lobsters.

TABLE 2. Weight (*g food/kg crab*) and frequency of occurrence of food items in crab stomachs.

Item	June 6–30, 1967			Sept. 21–Oct. 5, 1967		
	No.	%	*g/kg*	No.	%	*g/kg*
Total examined	202	–	–	28	–	–
Empty	59	29.2	–	–	–	–
Amorphous matter	71	35.1	1.6	23	82.1	2.2
Liquid	36	17.8	1.0	10	35.7	0.9
Polychaeta	39	19.3	1.0	5	17.8	0.3
Shell fragments	31	15.3	0.4	5	17.8	0.1
Sand	21	10.4	0.2	–	–	–
Eelgrass (*Zostera*)	9	4.4	0.1	–	–	–
Sea urchin (*Strongylocentrotus*)	8	4.0	<0.1	3	10.7	<0.1
Mussel (*Modiolus*)	6	3.0	0.2	9	32.2	0.1
Amphipoda	5	2.5	<0.1	1	3.6	<0.1
Pelecypoda	4	2.0	0.1	1	3.6	<0.1
Gastropoda	3	1.5	<0.1	1	3.6	<0.1
Porifera	3	1.5	0.1	–	–	–
Rhodophyceae	3	1.5	<0.1	–	–	–
Tunicata	3	1.5	<0.1	1	3.6	<0.1
Cumacea	2	1.0	<0.1	–	–	–
Asteroidea (*Asterias*)	2	1.0	<0.1	4	14.3	0.2
Chiton	1	0.5	<0.1	2	7.1	<0.1
Foraminifera	1	0.5	<0.1	–	–	–
Isopoda	1	0.5	<0.1	–	–	–
Turbellaria	–	–	–	1	3.6	<0.1
Cancer irroratus shell	–	–	–	1	3.6	<0.1

Distribution in Relation to Bottom Type

The sea bed from which crab samples were taken was classified as predominately bedrock, predominately boulders, or predominately sand. Bedrock in the study area is typically a flat, rather featureless, sandstone ledge cut by gullies with vertical or sometimes undercut sides. Boulders tend to be rounded and flat, 20–50 cm across, lying in patches in gullies or in larger areas surrounded by ledge or sand. In June, the numbers and biomass (standing stock) of crabs on sand and bedrock stations were less than on boulder stations (Table 3). Mean size of crabs on sand was significantly larger than elsewhere ($Z = 2.39$, $P < .05$); in fact, no crabs smaller than 65 mm were taken on sand, whereas crabs of all sizes were taken on boulder and bedrock. Many crabs taken by divers on sand were wholly or partly buried, particularly ovigerous females.

Elsewhere in Northumberland Strait, fishermen report that large numbers of commercial-sized crabs occur on mud. The September–October samples were taken after the 1967 year-class had begun to settle, and it was clear to the divers that *C. irroratus* either settles exclusively in rock areas, or that mortality is high where cover is scarce. The mean sizes of crabs on boulders and bedrock were not significantly different ($Z = 1.41$). The differences in standing stock and mean numbers per station (Table 3) possibly reflect the availability of cover and food on the two types of ground. Small crabs were frequently associated with gravel, sand, and softer sediments between boulders and in gullies, where they would derive some protection against predators.

Ecological Relationship with the Lobster (H. americanus)

Jefferies (1967) described *C. irroratus* in Narragansett Bay as being essentially an open sand dweller, unable to compete in rocky areas with *C. borealis* and possibly the lobster. This was attributed to the lighter, less massive claws of *C. irroratus*, and to its faster walking rate on sand. He suggested that should *C. borealis*, and possibly *Homarus*, be removed from Narragansett Bay, *C. irroratus* would extend its range into the rocky areas. *Cancer borealis* has not been found in Kouchibouguac Bay, whereas *C. irroratus* and lobsters are abundant. Small *C. irroratus* are particularly abundant on rocky or boulder areas, while larger crabs outnumber lobsters on sand (Table 3) and (from fishermen's reports) on mud. Stomach contents of lobsters show some similarity with those of crabs in the occurrence, for example, of polychaetes, starfish, sea urchins, mussels, and tunicates. One major difference is that lobsters prey extensively on crabs (D. J. Scarratt unpublished data), while there is no evidence that crabs prey upon lobsters.

Crabs and lobsters on boulder areas utilize the substrate in different ways. While crabs will bury themselves in the sediment or work their way under stones, they do not excavate or occupy burrows as the lobster does. Their defence, if disturbed while buried, is to attempt to settle further into the sediment, and they often betray their presence to divers while so doing. On rocky areas they are frequently found backed in against the base of rocks. They will adopt a defensive attitude if cornered, but usually attempt to escape. Lobsters, on the other hand, are well protected when in burrows, and have very efficient and seemingly more effective escape reactions.

Possible Effects of a Crab Fishery

The extent to which commercial productivity of crabs and lobsters may be related is difficult to assess. Since many mature crabs move off rocky areas onto sand or mud, a major part of the fishable crab population is not in direct competition with the lob-

Table 3. Numbers, sizes, and standing stocks of crabs, and the numbers of lobsters collected on different bottom types in Kouchibouguac Bay.

	No. stations	No. crabs	Mean carapace width±SD (*mm*)	Total weight (*g*)	Standing stock (g/m^2)	No. lobsters
Spring						
Sand	17	28	84.1±14.0	2699	1.9	6
Boulders	35	128	72.3±26.7	10345	3.5	349
Bedrock	27	54	65.3±27.7	3637	1.6	102
Total	79	210				457
Fall						
Sand	4	1	112.0	227	0.7	0
Boulders	10	89	49.0±27.7	3194	3.8	89
Bedrock	11	42	57.0±35.1	2460	2.7	90
Total	25	132				179

ster for food or space. Removal of some of the remaining large crabs from lobster grounds by fishing may leave space and energy available for other species, including lobsters, but in the absence of long-term experiments in natural conditions, the outcome is speculative.

Acknowledgments

We are indebted to Dr D. G. Wilder for making available the measurements of crabs from commercial lobster gear; to Messrs A. J. Wilson, A. F. Kenney, P. C. M. Fung, and U. J. Walsh for their assistance in the field; and to Mr A. Sreedharan for assistance with the mathematics.

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Changes in Gill Adenosinetriphosphatase Activity Associated with Parr–Smolt Transformation in Steelhead Trout, Coho, and Spring Chinook Salmon

W. S. ZAUGG AND L. R. MCLAIN

Western Fish Nutrition Laboratory
Bureau of Sport Fisheries and Wildlife, Cook, Wash. 98605, USA

ZAUGG, W. S., AND L. R. MCLAIN. 1972. Changes in gill adenosinetriphosphatase activity associated with parr–smolt transformation in steelhead trout, coho, and spring chinook salmon. J. Fish. Res. Bd. Canada 29: 167–171.

The average Na^+- and K^+-stimulated adenosinetriphosphatase (ATPase) activity of microsomes from gills of hatchery-reared coho salmon (*Oncorhynchus kisutch*) increased from about 12 μmoles ATP hydrolyzed/mg protein per hr during February through mid-April to approximately 24 in mid-May. Larger fish developed higher activities than smaller fish. Hatchery-reared spring chinook salmon (*O. tshawytscha*) exhibited a similar increase 2–3 weeks earlier.

In 2-year-old hatchery-reared steelhead trout (*Salmo gairdneri*), Na^+-, K^+-ATPase activities were elevated in some, but not all, smolt-appearing animals. Parr-appearing fish, including maturing males, showed no activity increase. When held in fresh water to July, steelhead smolts lost their silvery color and became more parr-like in appearance, and the previously elevated ATPase activity decreased to near pre-smolt levels. Yearling steelhead held at the laboratory showed a more consistent rise in ATPase activity.

The increase in transport ATPase (Na^+-, K^+-stimulated) activity occurring during parr–smolt transformation is probably a preparatory step for saltwater adaption and may also be closely associated with migratory disposition.

ZAUGG, W. S., AND L. R. MCLAIN. 1972. Changes in gill adenosinetriphosphatase activity associated with parr–smolt transformation in steelhead trout, coho, and spring chinook salmon. J. Fish. Res. Bd. Canada 29: 167–171.

L'activité moyenne de l'adénosinetriphosphatase (ATPase) stimulée par Na^+ et K^+ dans les microsomes des branchies de saumons coho (*Oncorhynchus kisutch*) élevés en pisciculture augmente de 12 μmoles environ d'ATPase hydrolysée/mg de protéine par h de février à la mi-avril à 24 à la mi-mai. Les gros poissons développent une activité plus grande que les petits. Les saumons chinook de printemps (*O. tshawytscha*) élevés en pisciculture font preuve d'un accroissement semblable deux à trois semaines avant les saumons coho.

Chez les truites steelhead (*Salmo gairdneri*) de deux ans élevées en pisciculture, l'activité de l'ATPase au Na^+ et K^+ s'accroît chez quelques-uns des individus à apparence de smolts. Les poissons à apparence de tacons, y compris les mâles en voie de maturation, ne démontrent aucun accroissement d'activité. Maintenus en eau douce jusqu'en juillet, les smolts de steelhead perdent leur coloration argentée, revêtant l'apparence de tacons, et le niveau préalablement élevé d'activité de l'ATPase retombe à peu près à celui des pré-smolts. Les truites steelhead d'un an maintenues en laboratoire présentent un accroissement plus régulier de l'activité de l'ATPase.

Cet accroissement de l'activité de l'ATPase (stimulée par Na^+ et K^+) au moment du passage du stade tacon à celui de smolt est sans doute une première étape d'adaptation à l'eau salée et peut être intimement liée aux préparatifs de la migration.

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MANY investigators have discussed the significance of the parr–smolt transformation in anadromous fishes relative to endocrine systems, migration patterns, body chemical composition, and saltwater adaption mechanisms (Barrington 1961; Hoar 1965; Baggerman 1960; Wagner et al. 1969). Studies on changes in body composition and weight–length ratios have been reported for coho salmon

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(*Oncorhynchus kisutch*) (Vanstone and Markert 1968) and steelhead trout (*Salmo gairdneri*) (Wagner 1968; Fessler and Wagner 1969).

Recently we reported that the Na^+-, K^+-stimulated ATPase activity of gill microsomes from coho salmon maintained under laboratory conditions at a constant 10 C increased about twofold during the last 2 weeks of March (Zaugg and McLain 1970). This change in biochemical activity seemed to be associated with parr–smolt transformation, and the present study was undertaken to discover if similar ATPase changes occurred in other species of anadromous fishes reared under both hatchery and laboratory conditions. We report results from coho salmon, spring chinook salmon (*O. tshawytscha*), and steelhead trout sampled from two local hatcheries prior to and during the period of parr–smolt transformation.

Materials and Methods

During the first 5 months of 1970, yearling spring chinook (adults return in April and May, spawning in August) and 2-year-old steelhead trout were taken from the Carson National Fish Hatchery, Carson, Wash., and coho salmon were obtained from the Willard National Fish Hatchery, Cook, Wash., for determinations of gill ATPase activity. Spring chinook were sampled again in 1971 along with yearling steelhead obtained in February from the Skamania Trout Hatchery, Washington State Department of Game, and kept at the laboratory throughout the experimental period. The coho salmon were released from the hatchery on May 15, 1970, a small number being held and fed at the laboratory for sampling on May 25 and June 2. This transfer resulted in an increase in water temperature from 6 to 10 C. On May 28, samples were retrieved from the Little White Salmon River approximately five miles downstream from the point of release.

Spring chinook salmon were reared on variations of the Oregon Moist Pellet, hatchery steelhead received Abernathy Dry Pellets, and coho salmon were fed Oregon Moist Pellet, variation IV. All hatchery-held fish and laboratory-held steelhead received normal daylight in water of 6–7 C.

ATPase activities were determined on preparations of gill microsomes as described elsewhere (Zaugg and McLain 1970). Reaction mixtures contained (mM): $MgCl_2$, 2.0; Tris, 25; ATP, 2.7; with NaCl, 50 and KCl, 10, added to determine Na^+ and K^+ stimulation above basic Mg^{2+}-dependent ATPase activity. Final *p*H was 7.0; volume, 1.5 ml; temperature, 30 C. Microsomes (0.03–0.1 mg protein) were added to start the reaction. Na^+-, K^+-stimulated ATPase activity is that increase over Mg^{2+}-dependent activity observed on addition of NaCl and KCl to the reaction mixture. Methods of sampling gill filaments from individual fish is described elsewhere (Zaugg and McLain 1970, 1971). Coefficient of condition was calculated from the relation $100W/L^3$, where W = weight in grams, and L = fork length in centimeters (Hoar 1939).

Results

Coho Salmon

The average Na^+-, K^+-stimulated ATPase activity of coho salmon gill microsomes increased from about 12 µmoles ATP hydrolyzed/mg protein per hr during February through to mid-April, to approximately 24 in May (Fig. 1A). This change appeared to be accompanied by a simultaneous decrease in coefficient of condition. The larger fish apparently developed higher activities than did the smaller fish (Table 1).

Spring Chinook Salmon

An increase in Na^+-, K^+-stimulated ATPase activity began after April 2 in spring chinook (Fig. 1B), preceding the same phenomenon in

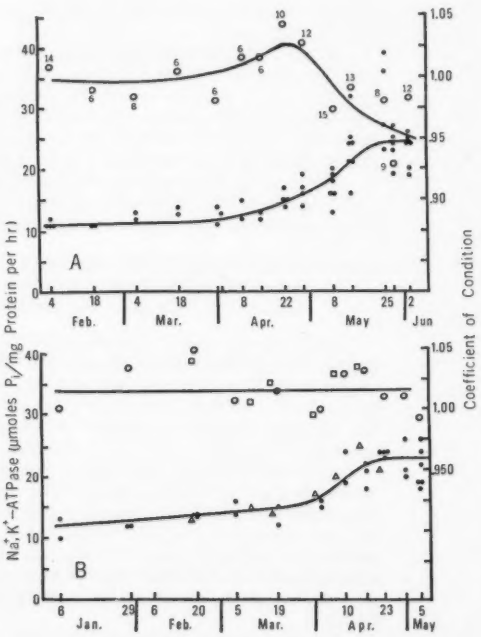

FIG. 1. ATPase activities in gill microsomes (●, 1970; △, 1971), and coefficients of condition (○, 1970; □, 1971), of hatchery-reared yearling coho salmon (A) and spring chinook (B) salmon. For ATPase activities, each point represents the average of duplicate determinations on combined gill samples from two or three fish; for coefficients of condition, the numbers of coho salmon used are indicated and for spring chinook each point represents the average for six fish. Fish sampled on May 25 and June 2 had been transferred from 6 to 10 C water on May 15.

TABLE 1. Na^+-, K^+-stimulated ATPase activities (μmoles ATP hydrolyzed/mg protein per hr)[a] in gill microsomes of coho salmon of various lengths before and at two intervals during the period of increasing activity shown in Fig. 1.

Fork length (*cm*)	Feb. 4–Apr. 14	Apr. 22–May 8	May 14–June 2
9.3–11.0	12±1(22)[b]	14 (3)	20 (2)
11.1–11.5	–	15 (2)	19 (2)
11.6–12.0	12±1(14)	14±1(5)	24±1(4)
12.1–12.5	12±1(14)	17 (6)	22±2(11)
12.6–13.0	12±1(9)	16 (3)	26±1(6)
13.1–13.5	–	20±1(6)	24 (3)
13.6–14.0	–	17±1(10)	25±1(7)
14.1–14.5	–	16 (2)	28 (5)
14.6–15.0	12 (3)	–	29 (4)
15.1–15.5	–	–	–
15.6–16.0	–	–	32 (1)

[a]Experimental conditions listed in Fig. 1.
[b]Number of fish in parentheses.

coho salmon by 2–3 weeks. The average increase was from 12–22 μmoles ATP hydrolyzed/mg protein per hr. There was no indication that larger fish developed higher ATPase activity than smaller fish.

Although average coefficients of condition were determined from small numbers of fish, values for 1970 and 1971 fell very near each other. Thus, variations suggested by the points in Fig. 1B may indicate real fluctuations, but larger samplings would be needed for conclusive evidence.

STEELHEAD

In tests from January 6 to May 12, 1970, on 47 steelhead trout (2-year-olds) (Fig. 2A), Na^+-, K^+-stimulated ATPase activity failed to increase in some animals, and low values were in evidence after the expected time of transformation. Activities were quite consistent until about mid-March or the first of April, when the points became widely scattered. A more consistent elevation of ATPase activity was observed with yearling steelhead held at the laboratory (Fig. 2B). After March all activities were above 20, whereas most activities in the 2-year-old group the previous year remained below 20 throughout the spring months. Average coefficients of condition appeared to decrease in April, but points are scattered because of small sample sizes.

Samples of gill filaments were taken for ATPase determinations from five individual steelhead once each month during May, June, and July (Table 2).

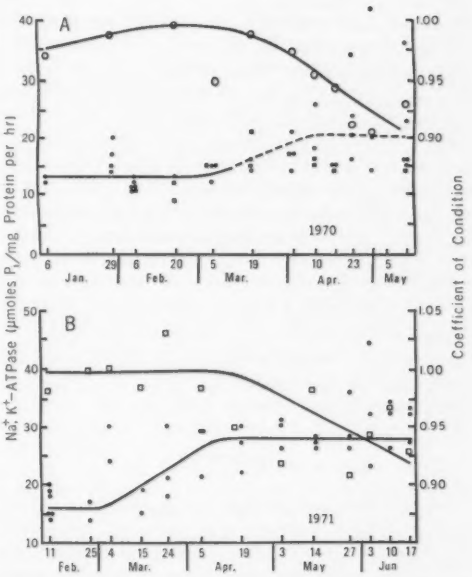

FIG. 2. ATPase activities in gill microsomes (solid symbols; ■, maturing or mature males), and coefficients of condition (○, 1970; □, 1971), of 2-year-old hatchery-reared (A) and yearling laboratory-held (B) steelhead trout. For ATPase activities, each point represents the average of duplicate determinations on a microsomal preparation from one fish; for the coefficients of condition, the average of all fish sampled on that date (indicated by the number of solid symbols in the ATPase curve).

TABLE 2. Na^+-, K^+-stimulated ATPase activities (μmoles ATP hydrolyzed/mg protein per hr) of gill microsomes[a] in five steelhead trout from May to July, along with coefficients of condition and fork lengths on June 4.

Fish	ATPase			Coefficient of condition (June 4)	Fork length (*cm*) (June 4)
	May 18	June 4	July 7		
1	12 (N)[b]	31 (N)	24 (N)	0.948	19.0
2	17 (I)	26 (I)	24 (N)	0.931	19.4
3	44 (S)	28 (S)	23 (N)	0.946	17.6
4	19 (N)	25 (N)	20 (N)	1.112	20.9
5	37 (S)	61 (S)	24 (N)	0.797	19.9

[a]Samples of gill filaments were taken from anesthetized fish as described elsewhere (Zaugg and McLain 1971).
[b]N, no silver color; I, intermediate, silver color but visible spots; S, very silvery, smolt-like.

Coefficients of condition and lengths are given for the June 4 sampling. The degree of silvery appearance was determined by visual observation, and each fish was classified as described in the table. General appearances changed very little from May 18 to June 4, but when sampled on July 7 all animals had lost their silvery appearance. Fish 1 and 4 did not exhibit the typical silvery appearance of smolts during the period of study, and only on June 4 was there any indication of a tendency toward elevated Na^+-, K^+-ATPase activity. Fish 2, although showing some silver coloring on May 18 and June 4, did not have elevated activity. Fish 3 and 5 exhibited typical smolt coloration on May 18 and June 4. By June 4, fish 3 had lost most of the elevated activity while fish 5 showed an increase. On July 7 all fish had reverted to lower activities.

Discussion

Experiments reported here and elsewhere (Zaugg and McLain 1970) show that Na^+-, K^+-stimulated ATPase of microsomes from coho salmon gill increases in activity during the early spring months. Observations of changes in appearance of these fish indicate that the rise in activity is closely associated with the parr–smolt transformation. In earlier experiments with coho salmon maintained at the laboratory in water regulated at a constant 10 C (Zaugg and McLain 1970), activity increased during the latter half of March. The present study reveals, however, that coho salmon held under hatchery conditions (water at 6 C) experience this change about 1 month later. The delay in development of increased activity likely resulted, at least in part, from a lower water temperature. Such an interpretation is consistent with the observation of Johnston and Eales (1970) that higher water temperatures result in earlier transformation of Atlantic salmon (*Salmo salar*), and with studies by van Overbeeke, reported by Hoar (1965), that show a similar temperature effect on transformation in coho salmon. In addition, fish in the previous study (Zaugg and McLain 1970) were larger, a factor which also contributed to earlier parr–smolt transformation.

In the earlier experiments mentioned above, which involved a relatively small number of coho salmon, we failed to see a definite relationship between the magnitude of ATPase activity increase and the size of the animals. Results reported here, however, indicate that larger fish develop higher activities (Table 1).

The preference for higher salinities, which occurs during transformation in coho salmon (Otto and McInerney 1970; Baggerman 1960), may be associated with an increase in transport ATPase (Na^+-, K^+-stimulated) activity of the gills. When the fish enter salt water, this activity continues to increase for 30–35 days until reaching a level 3–4 times that of freshwater coho salmon (Zaugg and McLain 1970). If the observed development of Na^+-, K^+-stimulated ATPase in smolts causes increased electrolyte excretions, as seems likely, these results support the observations of Houston and Threadgold (1963) that the parr–smolt transformation in Atlantic salmon is accompanied by a reduction in extracellular phase volume and an increase in volume of the cellular phase.

Spring chinook salmon that were reared in hatcheries for 16 months showed results generally similar to those of coho salmon. Whether gill ATPase activity increases in fall chinook fry, which are usually released from hatcheries in the spring of their first year, is unknown at the present time.

In contrast to the similarity observed in spring chinook salmon from one year to the next (Fig. 1B), results differed in the two groups of steelhead studied. Variations in 2-year-old fish, both in ATPase activity and in visual appearance, suggest that most of these fish could not be considered typical smolts. Many of the males were maturing or were already mature (Fig. 2A), a condition which, according to these and other unpublished observations, seems to prevent elevation of ATPase activity. Yearling steelhead held at the laboratory were more consistent in showing ATPase increase and in developing a silvery appearance. Thus, keeping steelhead in hatchery ponds longer than one year may, in some cases at least, result in a marked reduction in the number of true smolts capable of migrating.

Elevated Na^+-, K^+-ATPase activities of the two steelhead smolts studied by gill sampling methods on May 18 and June 4 (Table 2, fish 3 and 5) had decreased by July 7 to a level comparable to those in animals which failed to show physical changes characteristic of transformation (fish 1 and 4). The drop in Na^+-, K^+-ATPase activity detected in July must then be associated with regression in the ability of steelhead to adapt to salt water if held in fresh water beyond normal migration times (Conte and Wagner 1965). A drop in this activity in coho salmon has been reported (Zaugg and McLain 1970), but this was not accompanied by such a pronounced loss of the silvery appearance, and seemed to be characteristic of just those animals under 18 cm in length. Chinook salmon have not been examined for late summer decrease in ATPase activity.

Experiments reported in this paper show a close association between parr–smolt transformation and

elevated Na^+-, K^+-stimulated ATPase activity in gill microsomes of coho and spring chinook salmon. The same relationship exists in steelhead trout but is complicated by other factors, one of which is the early drop in previously elevated ATPase with an accompanying regression of saltwater adaptability and loss of silver color. We feel that the development of increased Na^+-, K^+-stimulated ATPase activity is a preparatory step for saltwater adaption and probably is intimately associated with migration disposition.

Acknowledgments

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Seasonal Distribution of *Chondrococcus columnaris* Infection in River Fishes as Determined by Specific Agglutinins[1]

M. P. FUJIHARA AND F. P. HUNGATE

Biology Department
Pacific Northwest Laboratories, Battelle Memorial Institute, Richland, Wash. 99352, USA

FUJIHARA, M. P., AND F. P. HUNGATE. 1972. Seasonal distribution of *Chondrococcus columnaris* infection in river fishes as determined by specific agglutinins. J. Fish. Res. Bd. Canada 29: 173–178.

River fish populations infected with *Chondrococcus columnaris* disease were surveyed by measurements of *C. columnaris* agglutinating antibodies in blood sera of fishes and by isolation of the pathogen using microbiological plating methods. Agglutinins were demonstrated in all 13 fish species collected except whitefish (*Prosopium williamsoni*). Blood serum from samples of fishes at four Columbia River sites during 1965 and three Columbia River sites and one Snake River site during 1969–70 demonstrated single annual cycles of *C. columnaris* antibody production. During the two annual sampling periods, the magnitude of antibody titers and frequency of fish with agglutinins increased in warm water and declined in cool water. The rise in titers occurred after a winter low, and usually followed the period when the first *C. columnaris* organisms were isolated from native fish. Agglutinating titers up to 1:5000 were found but most peak titers were between 1:320 and 1:640.

FUJIHARA, M. P., AND F. P. HUNGATE. 1972. Seasonal distribution of *Chondrococcus columnaris* infection in river fishes as determined by specific agglutinins. J. Fish. Res. Bd. Canada 29: 173–178.

Nous avons fait un relevé des populations de poissons fluviatiles infectés par *Chondrococcus columnaris* par titration des agglutinines de *C. columnaris* dans le sérum des poissons et séparation, au moyen de cultures, de l'organisme pathogène. Il est apparu des agglutinines dans chacune des 13 espèces récoltées, sauf le ménomini des montagnes (*Prosopium williamsoni*). Le sérum sanguin des poissons capturés à quatre stations d'échantillonnage du fleuve Columbia en 1965 et à trois stations du Columbia et une de la rivière Snake en 1969–70 manifeste un cycle annuel unique de production d'anticorps vis-à-vis de *C. columnaris*. Au cours des deux périodes annuelles d'échantillonnage, les titres d'anticorps et la fréquence des poissons possédant des agglutinines augmentent en eau chaude et diminuent en eau froide. Il y a élévation des taux d'anticorps après un minimum hivernal et généralement après l'apparition des premiers *C. columnaris* chez les poissons indigènes. Nous avons observé des titres agglutinants allant jusqu'à 1:5000, mais la plupart des titres de pointe se situent entre 1:320 et 1:640.

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YEARLY exposure, infection, and mortality of salmonids and river fishes to the pathogen *Chondrococcus columnaris* have been observed in the Columbia River since the causative organisms were first recovered from diseased fish by Fish and Rucker (1943), and by Ordal and Rucker (1944). Heavy prespawning mortality of sockeye salmon (*Oncorhynchus nerka*) in the Fraser River system in British Columbia has also been attributed to *C. columnaris* disease (Colgrove and Wood 1966).

Estimates of bacterial diseases in fish populations is typically dependent on isolation and identification of the pathogen from smear samples. This procedure is subject to error as it is difficult to obtain uniform and sufficient samples. Hence, a new method of estimating the extent of *C. columnaris* disease in fish populations was investigated.

Laboratory observations showed a 52% mortality of 1600 rainbow trout (*Salmo gairdneri*), approximately 3-months old, within a 6-week period following exposure to *C. columnaris* present as natural contaminants in Columbia River water (Fujihara and Nakatani 1971). Most of the survivors were resistant to subsequent infection which indicated the possible development of an immune response. The authors demonstrated that all year-plus rainbow trout surviving *C. columnaris* infection as juveniles developed agglutinating antibody titers ranging from 1:80 to 1:640 when naturally

[1]This paper is based on work performed under U.S. Atomic Energy Commission Contract AT(45-1)-1830.

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re-exposed to the disease for several months. Antibody titers up to 1:5120 were also produced in disease-free yearling rainbow trout by parenteral vaccination with heat-killed *C. columnaris* cells.

This ability to develop agglutinins against *C. columnaris* disease, supplemented with direct isolation of the pathogen was used to investigate the significance of seasonal changes in river temperature on: (1) the incidence of exposure, of prior and recent infection, and (2) as a measure of the severity of the disease in river fish populations. A knowledge of the temperature–disease relation and development of *C. columnaris* antibodies in fish populations is basic to a better understanding of the disease problem. Furthermore, the pattern and magnitude of antibody development may serve as a useful and objective method for the evaluation of the degree of *C. columnaris* fish infection and as a possible method to predict disease incidence in rivers.

Materials and Methods

Approximately 4000 fish of 13 different species were tested to determine seasonal *C. columnaris* exposure and infection of river fishes during 1965 and 1969–70. These included: largescale suckers (*Catostomus macrocheilus*), longnose sucker (*Catostomus catostomus*), northern squawfish (*Ptychocheilus oregonensis*), Columbia River chub (*Mylocheilus caurinus*), chiselmouth (*Acrocheilus alutaceus*), white sturgeon (*Acipenser transmontanus*), carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieui*), white crappie (*Pomoxis annularis*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), and mountain whitefish (*Prosopium williamsoni*).

Fish were sampled monthly using gillnets 200 × 6 ft deep with mesh sizes of 1, 1¼, 1½, and 2 inches, respectively, for each 50-ft section to obtain a representative size distribution. Nets were set during late afternoon and recovered the next morning. River temperature at each sampling location was recorded with a centrigrade field thermometer immediately after removal of 1-liter water samples from a depth of about 1 m. Figure 1 illustrates the sampling locations on the Columbia and Snake rivers.

Blood samples, smears of the gills and necrotic areas, if present, were plated upon removal of each fish from the net to avoid cross-contamination. Solid medium at *p*H 7.3 containing 1% Noble's agar, 0.4% Bacto-tryptone, and 0.04% Bacto-yeast extract was used for all surface streaking and plates were incubated at 25 C for 48 hr before examining for *C. columnaris* colonies. Fish were individually placed in labelled plastic bags and iced until kidney samples could be streaked for presence of the pathogen. A 0.5-ml blood sample for antibody determination was drawn asceptically from each live fish by either a heart or dorsal aorta puncture (Schiffman 1959), then cooled in an ice chest at 5 C until centrifuged to remove the sera. All plates and blood

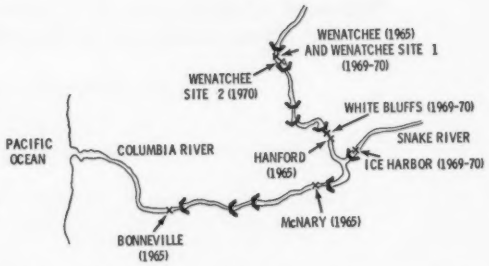

FIG. 1. Location of river fish sampling sites during 1965 and 1969–70.

samples from the same fish were numbered similarly to relate *C. columnaris* isolates to the presence of agglutinins.

A standard tube agglutination test (Conn 1957), using appropriate experimental controls, determined agglutinin values for fish serum samples. Heat-killed *C. columnaris*, at a concentration of about 4×10^8 organisms per milliliter in 0.85% saline was used as the test antigen. After 1 hr at room temperature agglutination tubes were refrigerated at 5 C for 18–20 hr before reading. The highest dilution of serum showing macroscopic agglutination was in each case recorded as the titer value.

Arbitrary definitions were used to define exposure and infection. Isolation of 1–10 surface *C. columnaris* organisms was considered an "exposure" and more than 10 surface isolates or one or more internal isolates an "infection".

Results

During 1965 more than 1000 largescale suckers were caught in fairly consistent numbers throughout the year. These fish were used as the representative species. The other species, except for whitefish, were consistent with largescale suckers in showing a fall maximum and a spring minimum frequency of fish with *C. columnaris* agglutinating antibodies. All species except whitefish for the 1969–70 sampling were used for the study.

Chondrococcus columnaris agglutinating antibodies occurred in largescale suckers throughout 1965 (Fig. 2) but no *C. columnaris* organisms were isolated by direct sampling from December through April. The numbers of fish exhibiting agglutinins dropped during this period and were probably residual from *C. columnaris* infection the previous year. The first *C. columnaris* isolates were obtained in early spring when the frequency of fish with agglutinins was lowest (Fig. 2). At no time were agglutinins not found, further indicating the presence of fish with residual antibodies. As river temperatures rose the numbers of fish with *C. columnaris* antibodies

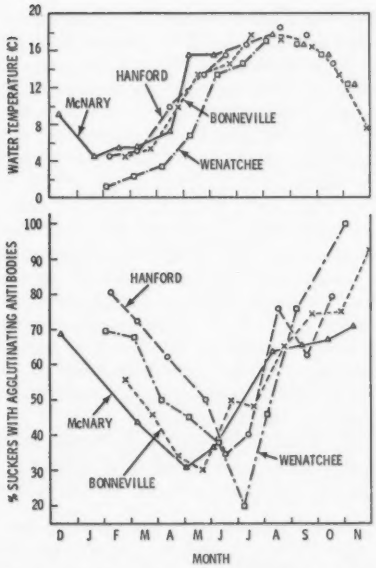

FIG. 2. Seasonal comparison of largescale suckers with *C. columnaris* agglutinating antibodies at four Columbia River sites, 1965.

generally increased at all sampling sites. This increase that usually followed the first isolation of organisms on external fish surfaces occurred between May and June. Maximum numbers of fish with agglutinins were caught during October through November when *C. columnaris* infection, as determined by direct plating, was generally the highest.

During 1969, maximum numbers of fishes with *C. columnaris* antibodies were observed from August through October during and following the peak annual temperatures and was generally similar to the earlier sampling period (Fig. 3). All sites followed the same general pattern of increase and diminution in numbers of fishes with agglutinins observed previously. Similarly, the first isolations of *C. columnaris* from external surfaces of fishes (May–June) corresponded to the start of increase in frequency of fishes with *C. columnaris* antibodies.

Snake River temperatures between July and October 1969 were approximately 2 C warmer than at White Bluffs and may have been responsible for the earlier and extended occurrence of high percentages of fishes with *C. columnaris* antibodies and higher disease incidence during this period.

Fish samples taken at Wenatchee site 1 during declining temperatures followed a similar pattern to the Snake River site (Fig. 3). Wenatchee site 2, heated by effluent from a manufacturing plant,

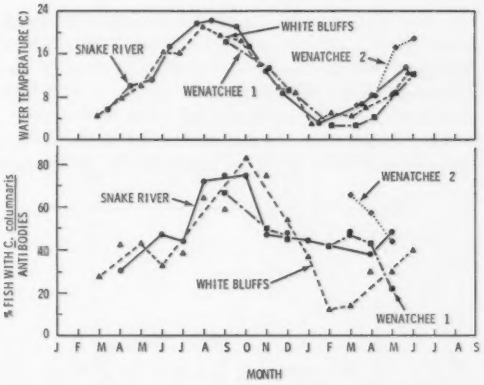

FIG. 3. Seasonal comparison of all species of river fish, except whitefish, with *C. columnaris* agglutinating antibodies at three Columbia River and one Snake River site, 1969–70.

was 4–7 C warmer than Wenatchee site 1 during similar sampling periods. It showed a higher frequency of fishes with *C. columnaris* antibodies than most other sites during similar sampling periods, but continued to decrease despite warmer temperatures because of the absence of fishes exposed to and infected by *C. columnaris*.

Seasonal changes in average agglutinating titers for largescale suckers during 1965 varied from about 1:20 to 1:60 between April and July, when smallest numbers of fish with agglutinins were observed (Fig. 4). Titer values rose sharply during the fall as did the frequency of incidence of the pathogen on fish.

In 1969–70, seasonal changes in average agglutinating titers for all river fishes, except whitefish, were considerably lower (Fig. 5). However, the pattern was similar to that in 1965 and showed an an increase and diminution in numbers of fishes with *C. columnaris* antibodies and magnitude of titers. The general pattern of antibody development was related to the frequency of *C. columnaris* infected river fishes and seasonal changes in water temperatures.

During 1965, the frequency for all species of river fish, except whitefish, exposed to *C. columnaris* disease as determined by direct plating methods was generally similar at all sampling sites except McNary (Table 1). The larger number of fishes exposed to and infected by *C. columnaris* at the McNary sampling site was consistent with the higher titers observed for largescale suckers at this location. *C. columnaris* disease incidence during 1969–70 was higher at the Snake River sampling site than at White Bluffs and may have been influenced by

the extended warmer Snake River water temperatures during the summer (Table 1). The disease incidence within the Hanford project area of the Columbia River (Hanford and White Bluffs sites) was also slightly higher during 1969 than 1965.

Since fishes were not sampled at Wenatchee site 1 until September 1969, a comparison of disease incidence was made between sites for similar months of sampling (Table 2). The Snake River site was highest and Wenatchee site 1 showed the lowest frequency of both exposed (noninfected) and infected fishes. Wenatchee site 2 was free of *C. columnaris* until organisms were evident on fishes in other sections of the river. The higher frequency of these fishes with agglutinins, higher titer magnitude (see Fig. 3 and 5) and lack of *C. columnaris* isolates from March through May indicate that these fishes were not permanent residents of the warm water area during the winter and spring months, but spent sufficient periods in the cooler part of the river. *C. columnaris* agglutinating antibodies were observed in 30% more of these fishes, and average titers were at least twice as high as observed for fishes sampled upstream at Wenatchee site 1 during similar periods.

No *C. columnaris* antibodies were shown in blood sera from several hundred whitefish taken over the two sampling periods. In the laboratory,

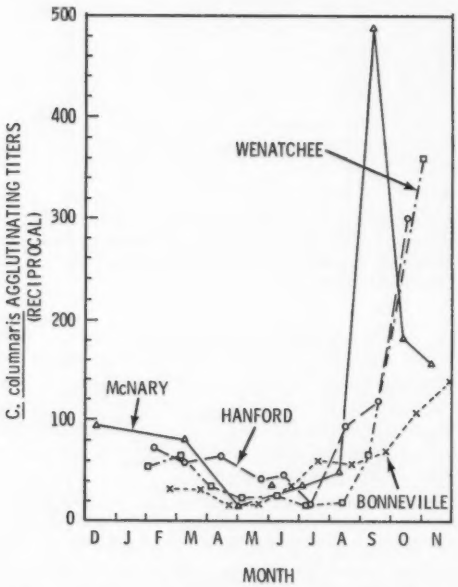

FIG. 4. Seasonal changes in average *C. columnaris* agglutinating antibody titers in largescale suckers at four Columbia River sites, 1965.

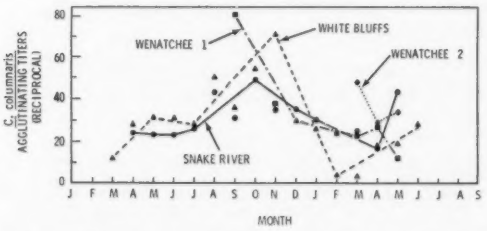

FIG. 5. Seasonal changes in average *C. columnaris* agglutinating antibody titers in all species of river fish, except whitefish, at three Columbia River and one Snake River site, 1969–70.

TABLE 1. Incidence of *Chondrococcus columnaris* disease among river fishes at selected Columbia River sites in 1965 and 1969 and at one site on the Snake River in 1969.

Location	Sampling period[a]	Temp (C)[b]	No. fish	Disease incidence[c]	
				% exposed	% infected
	1965				
Bonneville	6/23–11/29	14.7–7.8	498	6.0	2.0
McNary	5/2–11/10	15.6–12.2	370	11.6	4.3
Hanford	6/16–10/17	15.6–14.4	205	8.3	1.9
Wenatchee	6/9–11/2	13.3–13.3	256	6.2	1.9
	1969				
Snake R.	6/11–10/31	17.2–12.8	213	15.0	4.2
White Bluffs	6/3–1/5/70	16.1–3.3	441	10.0	2.0

[a]Dates of first and last *C. columnaris* isolations at each site.
[b]Temperatures during first and last *C. columnaris* isolations at each site.
[c]Arbitrary definitions: 1–10 surface isolates/fish, exposed (not infected); > 10 surface isolates/fish, infected; 1 or more internal isolates/fish, infected.

TABLE 2. A Comparison of *Chondrococcus columnaris* disease incidence among river fishes from September 1969 through the start of the *C. columnaris* season in 1970.

Location	Sampling period[a]	Temp (C)[b]	No. fish	Disease incidence[c]	
				% exposed	% infected
Snake R.	9/17/69–10/31/69	21.1–12.8	98	12.2	5.1
	5/21/70–	13.3	46	4.3	2.2
White Bluffs	9/24/69–1/5/70	18.3–3.3	248	9.7	3.2
	5/1/70–	8.3	50	2.0	0
Wenatchee Site 1	9/3/69–3/9/70	18.3–2.8	181	4.4	2.2
Wenatchee Site 2	6/3/70–	18.9	43	13.9	0

[a]Comparison of *C. columnaris* isolations at Snake River, White Bluffs, and Wenatchee site 1 since test was initiated at Wenatchee site 1 in September 1969. Wenatchee site 2 sampled from March 1970; no *C. columnaris* isolates until June 1970.

[b]Temperatures during *C. columnaris* isolations.

[c]Arbitrary definitions: 1–10 surface isolates/fish, exposed (not infected); > 10 surface isolates/fish, infected; 1 or more internal isolates/fish, infected.

however, whitefish challenged intraperitoneally with about 2.5×10^5 heat-killed organisms and 25% complete Freund's adjuvant consistently developed titers from 1:10 to 1:160 within a month post injection. When the cells plus adjuvant were administered a second time, antibody titers up to 1:1280 were produced within an additional week.

Discussion

Studies by other investigators have illustrated that fishes exposed to bacterial antigens produce an immune response against the offending pathogen (Smith 1940; Cushing 1942; Krantz et al. 1964; Klontz 1966; Post 1966; Snieszko 1970).

Using antibody production as an index of infection of river fishes to *C. columnaris*, our data suggest peak yearly effective infection of at least 70–80% of most adult river fish species to the disease (Fig. 2 and 3). Data from direct isolation methods (Table 1) showed 6–15% exposure and 2–4.3% infection. The incidence of *C. columnaris* exposure and infection of fishes in most instances is clearly related to river temperatures above 13 C, the frequency of fish having antibody titers, and magnitude of antibody titers. Exposure and infection of river fish populations to *C. columnaris* disease in the river, however, is not a static condition and was shown to vary widely from year to year.

The abrupt rise of antibody titer magnitude from July through November (Fig. 4 and 5) follows by several months the first recoveries of *C. columnaris* organisms from fish and follows by 1–2 month rise of frequency of fish with demonstrable agglutinins. This is not unexpected since high titers are routinely the consequence of repeated and/or continuing infection. The data now available are insufficient to indicate whether frequency of antibody titers, magnitude of antibody titers, or both will be most useful as a measure of severity of the disease in different years. In any case, it is clear that the antibody method is a sensitive and reliable indicator of disease status in river fish populations. However, presence of viable organisms gives an indication of direct change of disease state and is equally necessary for disease studies.

Since anadromous salmonids are moving through the same water occupied by other river fishes, continued monitoring of river fishes provides an indication of disease state expected in the more valuable salmonid species. This is specially true of fish ladders where unusually favorable conditions exist for disease transmission (Fujihara and Hungate 1971). A continuing survey of antibody levels in anadromous salmonids, during different phases of their migration, would be helpful in more positively relating their disease state to general or local factors affecting them.

The higher *C. columnaris* exposure, infection and antibody production rates at the McNary and Snake River sampling sites are at this time unexplained. The disease state at the McNary site may have been influenced by the warmer water flow of the Snake River into the Columbia River. Highest summer temperature near the mouth of the Snake River was about 2 C higher (24 C) during 1965 and 1–3 C higher (22 C) during 1969 than observed at the Columbia River sampling sites during similar months. The significance of seasonal river tem-

perature changes at the various sampling sites on the incidence of exposure and infection of fishes to *C. columnaris* disease could not definitely be established. A larger temperature differential than normally occurs between the Snake River and the Columbia River would be necessary to positively determine whether the greater disease incidence at the Snake River site was directly related to the slightly warmer temperatures. *C. columnaris* disease conditions may be enhanced more by extended periods of moderately warm temperatures and low river flow during the summer rather than by peak summer water temperatures.

Whitefish appeared to be resistant to natural infection by *C. columnaris* although a few viable organisms were occasionally isolated from the gills. These observations indicate that this species may be able to produce and secrete either a bacteriostatic substance or have a unique surface bacterial flora capable of preventing invasion of *C. columnaris* into its tissues. Identification of the means by which whitefish resist *C. columnaris* disease may be valuable since it might lead to a general protective agent.

Of particular interest was the identification of psychrophilic *C. columnaris* organisms at the White Bluffs and Wenatchee 1 sampling sites at minimal temperatures of 3.3 and 2.8 C respectively, during the winter of 1970 (Table 2). Psychrophilic *C. columnaris* organisms have not previously been identified in the Columbia River system and may be a new source of infection to fishes.

Acknowledgments

The authors express their appreciation to Dr R. C. Thompson and Dr W. R. Wiley for their review of the manuscript. The technical assistance of Mr R. L. Tramel and Mr J. L. Armantrout is also gratefully acknowledged.

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Differences in Atlantic Salmon, *Salmo salar*, from North America and Europe

O. L. NYMAN[1] AND J. H. C. PIPPY

Fisheries Research Board of Canada
Biological Station, St. John's, Nfld.

NYMAN, O. L., AND J. H. C. PIPPY. 1972. Differences in Atlantic salmon, *Salmo salar*, from North America and Europe. J. Fish. Res. Bd. Canada 29: 179–185.

Differences in electropherograms produced by serum proteins and liver esterases were used to identify North American and European Atlantic salmon (*Salmo salar*) caught at sea. Division of salmon according to continent of origin was supported by mean river age, mean fork length, and abundance of the two parasites *Anisakis simplex* and *Eubothrium crassum*. Consistent differences in electrophoretic behaviour of serum proteins and liver esterases in salmon from the two continents support the suggestion that salmon from North America and Europe represent different subspecies.

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Le comportement caractéristique des protéines sériques et des estérases hépatiques sur électrophorégrammes ont permis aux auteurs de distinguer les saumons atlantiques (*Salmo salar*) d'Amérique du Nord de ceux d'Europe capturés en mer. De plus, la durée moyenne de vie en rivière, la longueur moyenne à la fourche et l'abondance de deux parasites, *Anisakis simplex* et *Eubothrium crassum* ont confirmé l'identification du continent d'origine. Les différences uniformes dans le comportement électrophorétique des protéines sériques et des estérases hépatiques de saumons provenant des deux continents supportent l'hypothèse que les saumons d'Amérique du Nord et ceux d'Europe constituent deux sous-espèces distinctes.

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SINCE 1955 it has been established that Atlantic salmon (*Salmo salar*) from both North America and Europe frequent oceanic and coastal areas off West Greenland (Nielsen 1955, 1961; Menzies and Shearer 1957; Pyefinch 1958; Swain and Hartley 1962; Carlin 1962, 1969; Allan and Bulleid 1963; Hansen 1965; Saunders et al. 1965; Went 1965). These joint feeding grounds have been exploited to an increasing degree in the last decade by driftnetters primarily from the Scandinavian countries (Saunders 1966). The potential impact of these operations on the fishing industry and salmon stocks in home waters prompted a joint working party of the International Commission for the Exploration of the Sea and the International Commission for the Northwest Atlantic Fisheries to recommend an investigation of the stock composition of the Atlantic salmon in West Greenland. One approach to this problem involved a search for a natural or "biological" tag that could be used to identify salmon stocks in the area. Templeman (1967) pointed out that the incidence of the tapeworm *Eubothrium crassum* might be different in salmon from either side of the Atlantic. He also indicated that most salmon from European rivers spend 2 years in fresh water before migrating to sea while most North American salmon spend 3 years in the rivers. Another approach, based on electrophoretic examination of salmon tissues, was suggested by Nyman 1966 and 1967. Nyman (1966) found differences in serum protein and liver esterase patterns between 2-year-old Canadian and Swedish salmon reared under identical conditions. A year later (1967) he detected similar differences in samples from the same groups of juvenile salmon. Examination of serum from Canadian–Swedish salmon hybrids led to the conclusion that genetic material affecting the location of one of the bands was "segregated to the offspring ... in a manner that may indicate a co-dominant relationship between two alleles". The genetic background (if any) of the differences noted in liver esterase patterns of juvenile salmon from Canada and Sweden Nyman (1966, 1967) was not clear. In a preliminary to the present investigation the serum

[1]Present address: Institute of Freshwater Research, S-170 11 Drottningholm, Sweden.

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protein patterns and liver esterases of 278–950 juvenile and adult salmon from various countries (Table 1) were examined and the same differences as noted by Nyman were found among fish from North America and Europe.

In the study reported here the differences reported by Nyman were used to identify North American and European salmon off West Greenland. Studies were carried out on the age composition of smolts, fork length, and parasite fauna of most specimens to supplement the biochemical technique. Results of these investigations were then compared with data from tagged Canadian salmon recovered off Greenland to establish the validity of the original separation.

Materials and Methods

A total of 242 adult salmon (blood and liver tissues) of unknown origin caught off West Greenland by the Canadian fisheries research vessel *A. T. Cameron* during the fall of 1969 and 25 salmon caught in the Labrador Sea by the same vessel during the spring of 1970 (Fig. 1) were examined electrophoretically. In these two samples only fish belonging to the same sea-age classes (one and two sea winters, respectively) were considered for determination of age, length, and abundance of adults of the tapeworm *E. crassum* and larvae of the nematode *Anisakis simplex*.

Analyses were also carried out on a total of 93 Canadian tagged salmon caught in Greenland in 1969. They originated in several Canadian rivers but a high proportion came from the Miramichi River system. During the summer of 1970, sera, liver, and kidney tissue of a total of 140 salmon caught off Newfoundland (Bonavista and St. Anthony) and sera from 34 specimens in various Icelandic streams were analysed.

Blood was withdrawn from the caudal vein employing B-D's Vacutainer system, with liquid EDTA serving as anticoagulant. These tubes were submerged in ice-water until each catch had been sampled. Then the blood was transferred to the polyethylene test tubes of the Beckman Spinco Analytical system and spun for 35 sec in the Microfuge at 20,000 rpm. The supernatant sera were then immediately transferred to new test tubes and stored at –20 C until analysis.

Livers were collected as soon as possible after blood sampling, placed in plastic bags, and frozen. Before analysis a 3 cm^3 portion of each organ was ground in a Sorvall homogenizer in an equal amount of gel-buffer (Ashton and Braden 1961) for 2 min at top speed. The resulting slurry was transferred to polyethylene test tubes and centrifuged for 15 min. The supernatant was used for electrophoretic analysis, either directly or after storage in a freezer.

For the analyses, a standard model of water-cooled (1–7 C) horizontal starch gel electrophoretic apparatus was employed. Detachable buffer vessels were used for rapid changing of buffer systems. Wettex sponge cloths were employed to connect the electrode buffer with the gel surface. The gel plate allowed 40 specimens to be analysed simultaneously; six of these were of known continental origin. After electrophoresis the gel slab was sliced horizontally, one slice being stained with Amido Black, the other with Coomassie Brilliant Blue (or for detection of transferrin zones: Nitroso R salt according to the method by Mueller et al. 1962).

The basic buffer system employed in studies on livers and sera was that of Ashton and Braden (1961), the electrode buffer being 0.029 M lithium hydroxide and 0.191 M boric acid, and the gel-buffer being 0.0076 M citric acid and 0.051 M Tris. Electrophoresis was conducted for 105 min at 400 v. Two additional buffer systems were also used for the sera. The first was that of Aronsson and and Grönwall (1957) modified according to de Ligny (1967), the standard solution being 0.5 M Tris, 0.075 M boric acid, and 0.021 M EDTA (disodium salt), the electrode buffer being a threefold dilution of standard buffer with the *p*H adjusted to 8.9, and the gel-buffer being 125-ml standard buffer, 1.5 g EDTA, and 1.15 g boric acid in 875 ml of distilled water, and the *p*H adjusted to 8.2. Electrophoresis was for 3.5 hr at 350 v. The second was that of Gahne (1966), the electrode buffer being 0.06 M lithium hydroxide and 0.229 M boric acid, and the gel-buffer consisting of 1 volume of electrode buffer and 5.4 volumes of Tris-citric acid (0.079 M tris + 0.007 M citric acid). Electrophoresis in this system was for 2 hr at 300 v.

For detection of general proteins a small amount (about 2 ml) of Amido Black stock solution (60 ml acetic acid, 5 g Amido Black, and 150 ml glycerine in 300 ml distilled water) was spread over the gel surface. After 2 min excess dye was rinsed away in a 5:5:1 solution of distilled water, methanol, and acetic acid. The gel was agitated in this destaining solution overnight before photographic recording.

Proteins were also detected using Coomassie Brilliant Blue, according to Chrambach et al. (1967): 1:20 dilution in 12.5% TCA (Trichloracetic acid) of a 1% aqueous stock solution of Coomassie Brilliant Blue R 250.

TABLE 1. Numbers of salmon from various countries used in preliminary electrophoretic analyses (sr = sea-run; ll = landlocked).

	Sweden (sr + ll)	Finland (ll)	Norway (ll)	Scotland (sr)	Ireland (sr)	Canada (sr + ll)	USA (sr)	Total
Serum	713	5	20	32	30	126	24	950
Liver	165	5	20	15	21	52	–	278

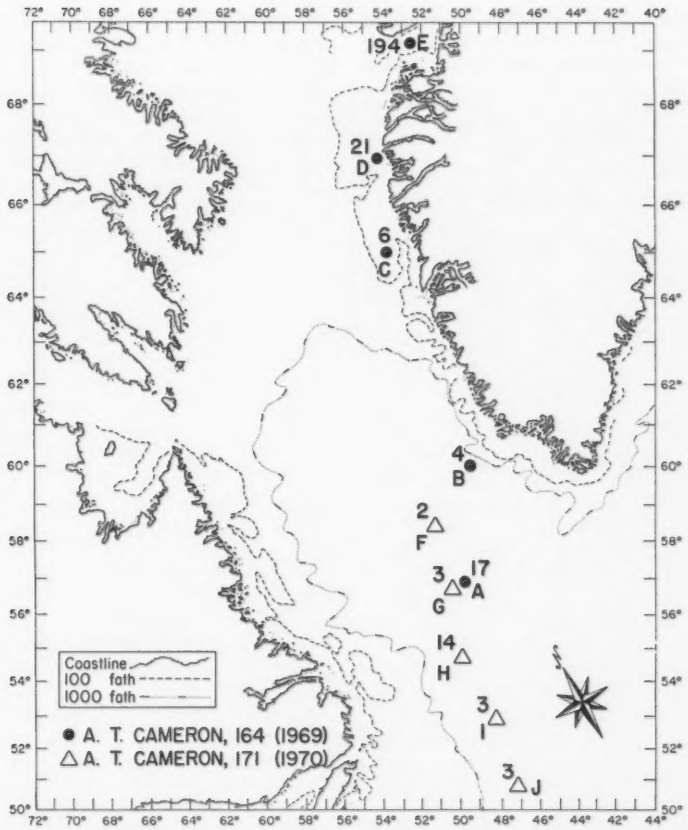

FIG. 1. Locations of the ten major sampling areas. Numbers indicate number of salmon examined, the capital letters refer to sampling station codes.

After 30 min of staining the gel was transferred to 10% TCA and photographed after 48 hr.

Transferrin zones were detected with Nitroso R reagent, according to Mueller et al. (1962): Ferric ammonium sulphate was added to the serum in an amount equivalent to about 5 μg of Fe^{+++} per milliliter serum and the mixture incubated for 15 min in the following solution: 0.5 g Nitroso salt, 1 g hydroxylamine hydrochloride, 2.7 g sodium acetate ($3H_2O$), and 1.5 ml glacial acetic acid. The gell was then washed with sthe ame destaining solution as used for Amido Black.

Nonspecific esterases were detected after incubation in a sodium phosphate buffer of *p*H 7.0 (Burstone 1962) for 15 min after which the following staining solution was added: 100 mg Fast Red TR salt, 50 ml distilled water, and 1 ml 1% solution of alpha naphthyl acetate in equal amounts of distilled water and acetone. Destaining was the same as above.

Abundance of larvae of the nematode *A. simplex* free in the body cavity or encysted on the visceral peritoneum and in the muscle layers of the alimentary canal was determined with the use of ultraviolet light (Sinnhuber and Law 1949) as described by Pippy (1970). The presence or absence of adults of *E. crassum* was determined by slitting open a sample of 15 pyloric caecae and opening and examining the pyloric region of the intestine. Preliminary studies had shown these to be the normal localities for the tapeworm.

Frequency distributions of *A. simplex* larvae were skewed and had variances much greater than their means, indicating they would require logarithmic transformation before analytical methods appropriate to normal distributions could be applied. The correct transformation to be used was determined from estimates of K (Barnes 1952) where:

$$K = \frac{\bar{x}^2}{S^2 - \bar{x}}$$

when $\bar{x}$ is the distribution mean and S the standard

deviation. Since K values for *Anisakis* in biochemically identified, American and European salmon were .72 and 1.17, respectively, the following logarithmic transformation was indicated (Barnes 1952):

$$Y = \log_e (x+1).$$

The K value for North American tagged fish was greater than 2 (2.30), and the transformation used (Barnes 1952) was:

$$Y = \log (x+\tfrac{1}{2}K).$$

These transformations stabilized the variance and altered the distributions.

Biochemical Characters

North American and European salmon taken off Greenland could be separated primarily on the basis of two independent systems in the blood sera, those proteins staining with Amido Black and those with Coomassie Brilliant Blue. Liver esterase zymograms were less useful in classifying fish as to continent of origin; only about 20% could be classified.

Separation with system I was based on the relative position of band 4 (Fig. 2, system 1) (= zone a of Nyman 1966) when employing the buffer system by Ashton and Braden (1961) and subsequent staining with Amido Black or Coomassie Brilliant Blue. This band stained positively (faint green) by Nitroso R salt, a sensitive iron indicator. Sera were classified by measuring the distance from this zone (G1) to the slowest migrating albumin (Alb) (Fig. 3). The separation in 50 fish classified as being of "North American" origin was 3.58–3.68 mm (mean 3.63) and that for "European", 3.80–3.88 mm (mean 3.85). Improved separation of these two zones was obtained when using the buffer system by Aronsson and Grönwall (1957) as modified by de Ligny (1967). This method allowed direct visual classification of individual fish (Fig. 4). Separation with system I was always performed with both buffer systems to minimize reading errors.

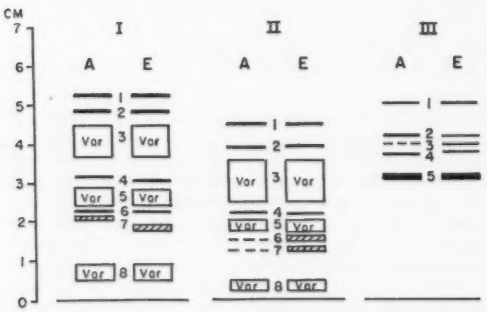

FIG. 2. Generalized electropherograms of the three protein systems discussed in this paper. A = North American, E = European. The scale to the left indicates anodic migration in centimeters. Var = zones with intraspecific variation. System I = blood serum proteins, buffer system by Ashton and Braden (1961). System II = blood serum proteins, buffer system by Gahne (1966). System III = liver esterases, buffer system by Ashton and Braden (1961). Bands with same number in Systems I and II are identical.

Classification with system II was based on the relative staining intensity of bands 6 and 7 (Fig. 2 and 5) when stained with Amido Black or Coomassie Brilliant Blue and employing the buffer system suggested by Gahne (1966). These bands are much more intense in European salmon and correspond to zone b of Nyman (1966) who used the buffer by Ashton and Braden (1961). The buffer system used here augmented the difference reported by Nyman. Comparison with human sera indicated that this zone consists of globulins.

The locations of some of the faint bands in the blood serum electropherograms of salmon from both sides of the Atlantic were variable ("Var", Fig. 2). Some of these variations (transferrins) are probably genetically controlled and may be of value for interpopulation comparisons (D. Møller 1969 personal communication).

The somewhat slower migration of the liver esterase band 4 and the much lower enzyme activity of band 3 in American salmon was clearly visible in system III after 5 min of staining (Fig. 2, III; Fig. 6) when only the most prominent bands had developed. These differences are consistent in juvenile salmon but may show extensive quantitative variation in adult sea-run fish, thereby obscuring classification. Thus, only about 20% of the adult salmon examined could be positively typed according to liver esterases.

North American salmon made up 43% of all the salmon examined from off West Greenland. However, the proportion of salmon from each continent varied greatly with time and locale. This wide variation is likely the result of small sample sizes. In only two of these instances were there any discrepancy among the three systems. All others gave identical results. The two exceptional cases were grouped with the European salmon according to the sera electropherograms (systems I and II).

Approximately 48% of the 25 salmon caught in the Labrador Sea in April 1970 were identified as being of North American origin (Fig. 1). In contrast all but one of the 140 specimens collected in Newfoundland in 1970 were identified as North American. All of the 34 Icelandic salmon had patterns similar to the European salmon.

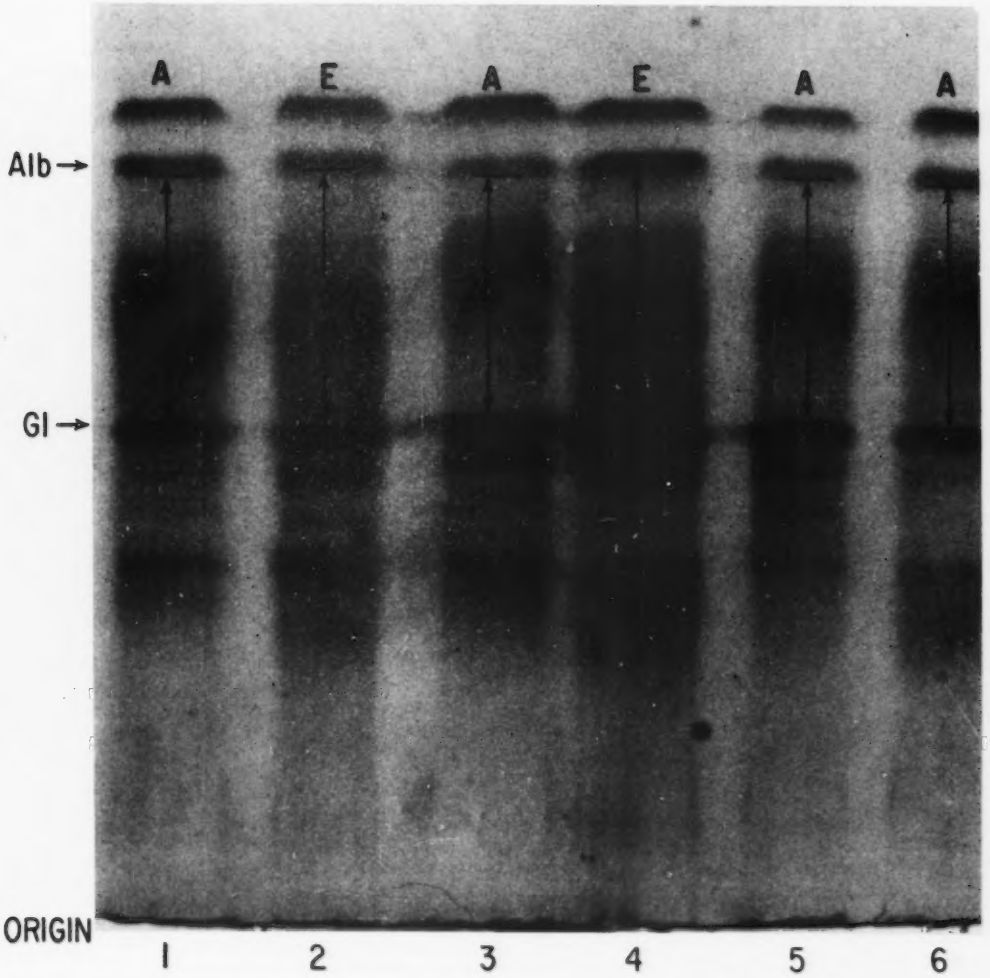

FIG. 3. Classification of serum proteins (System 1) by measuring distance between a globulin zone (G1) and the slowest migrating albumin (Alb). Photograph of electropherogram enlarged twice to facilitate measuring. Distance given to the nearest one-hundredth of a centimeter. Specimens 1 and 5 are from New Brunswick; 3 is from a land-locked salmon, and 6 from a sea-run salmon, both from Newfoundland. Specimen 2 is from Ireland and 4 from Sweden.

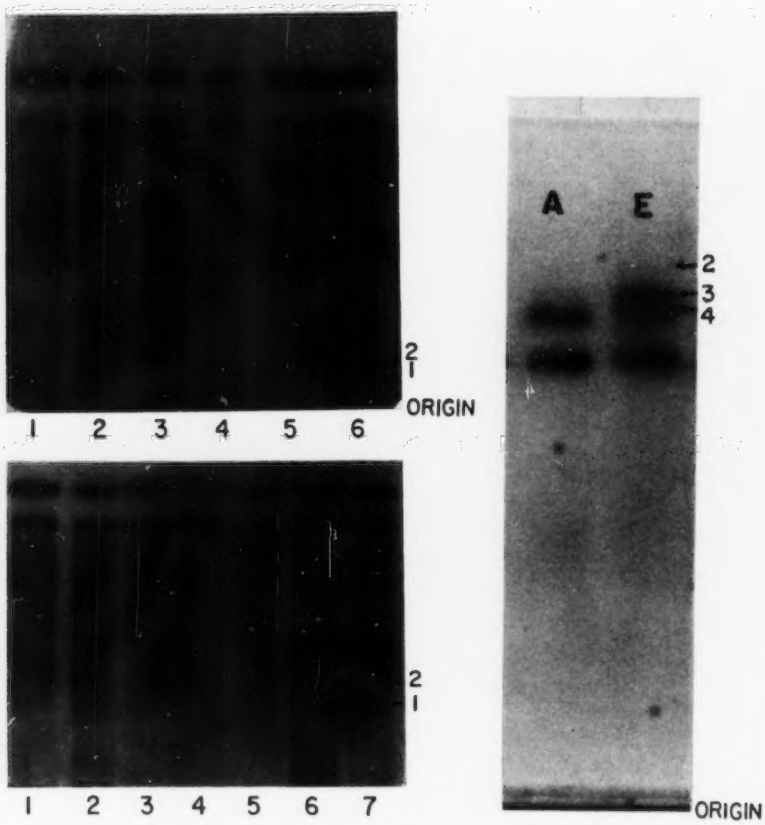

FIG. 4. (*Top left*) Original size of the fastest portion of sera electropherograms employing a modification of the buffer by Aronsson and Grönwall (1957). Note the more anodic position of band 2 in specimens 1, 3, and 5 that are North American salmon as compared to the position of band 1 in specimens 2, 4, and 6 that are European. (1 and 3 from New Brunswick, 5 from Newfoundland, 2 and 4 from Ireland, 6 from Sweden).

FIG. 5. (*Bottom left*) Blood serum electropherograms employing the buffer by Gahne (1966). Note that bands 1 and 2 are in European specimens (2, 4, and 6) and almost completely missing in North American specimens (1, 3, 5, and 7). (1–6 are the same fish as in Fig. 4, specimen No. 7 is from Newfoundland.

FIG. 6. (*Right*) Liver esterase zymograms of juvenile salmon after five minutes incubation. A = North American, E = European salmon. The differences at positions 3 and 4 are discussed in the text.

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Evidence Supporting Stock Identifications

Student's *t*-test indicated that the mean smolt age (Table 2) of biochemically identified European salmon (2.27) was lower ($P < .01$) than that of similarly identified North American salmon (2.87). Also, the mean smolt age of Canadian tagged salmon (2.94) caught in Greenland during the same period was similar ($.6 < P < .7$) to that of biochemically identified North American salmon but higher ($P < .005$) than that of European salmon. Similarly, a chi-square test on smolt age distributions indicated that biochemically identified European and North American salmon had different ($P < .005$) age distributions. However, it is of interest to note that the age distribution of biochemically identified North American salmon was different ($P < .005$) from that of the tagged Canadian salmon. Since a high proportion (.98) of these tagged salmon originated in the Miramichi River system, this difference is likely indicative of the diverse stocks of North American salmon represented in Greenland as reported by Saunders et al. (1965).

Mean fork lengths of Canadian tagged (62.98 cm) and biochemically identified (65.58 cm) North American salmon in West Greenland were lower ($P < .01$) than those of biochemically identified European salmon (68.43 cm) (Fig. 7). Also, the mean fork length was significantly lower ($P < .01$) for tagged Canadian salmon than for biochemically identified American salmon. This difference may be related to reduced size resulting from tagging, as previously observed in tagged Atlantic salmon (Saunders and Allen 1967) and redfish (Kelly and Barker 1963).

Student's *t*-test indicated a highly significant difference in the abundance of *A. simplex* between biochemically identified European and American salmon off West Greenland (Table 3). Also, *A. simplex* was found in similar numbers in tagged Canadian and biochemically identified American salmon (Fig. 8).

Table 2. Smolt ages of 231 1-sea-year salmon caught off West Greenland in September–October 1969 and identified as to continent of origin biochemically or from tags.

Identification	Smolt age in years %						Mean	No. fish examined
	1	2	3	4	5	6		
Europe	6	70	16	7	1	0	2.27	100[a]
North America	1	38	41	13	5	1	2.87	76[a]
Canadian tagged	0	15	76	9	0	0	2.94	55[b]

[a]Two fish were omitted from the total examined (178) because smolt ages could not be determined.

[b]Only those salmon not originating in hatcheries were considered for comparison because the smolt ages of wild salmon were considered to be more representative of the actual stock composition in Greenland.

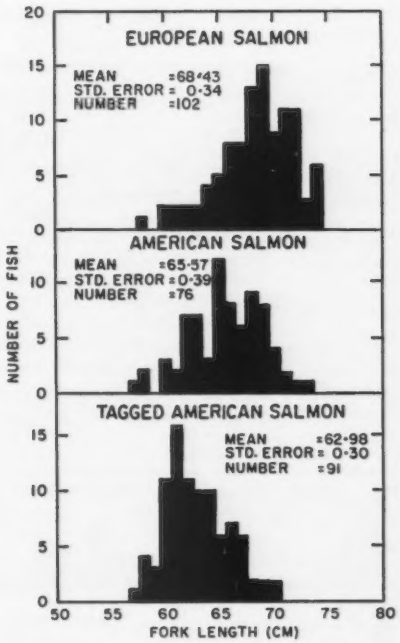

Fig. 7. Distribution of fork lengths of tagged Canadian salmon and biochemi cally identified North American and European salmon caught off West Greenland in 1969. (The number of tagged Canadian salmon examined (91) is less than that reported in Table 3 (93) because fork lengths were not available for two of these fish).

The incidence of *E. crassum* in biochemically identified North American salmon (22.4% of 76) was significantly higher ($.05 < P < .1$) than in the European salmon (11.8% of 102).

Mean fork length, abundance of *A. simplex*, and incidence of *E. crassum* in the biochemically identified European and North American salmon from the Labrador Sea show a trend similar to that found in the large Greenland sample the previous fall. However, the differences encountered here were not significant at the 95% level. The mean smolt age was almost identical for the two groups.

Discussion

The results obtained in this study indicate that the differences reported by Nyman (1966, 1967) between North American and European salmon can be used

TABLE 3. Intensity of infestation of *A. simplex* in salmon samples from West Greenland, 1969.

	Biochemically identified			
	American	European	Total	Tagged Canadian
No. salmon examined	76	102	178	93
No. parasites found	344	736	1080	403
Original data				
Mean	4.53	7.22	6.07	4.33
Variance	31.91	50.38	44.27	12.16
Transformed data				
Mean	1.321[a,b]	1.791[a]	1.590	1.475[b]
Variance	0.747	0.658	0.749	0.680

[a]Student's t value = 3.693 and $P < .01$.
[b]Student's t value = 1.174 and $.2 < P < .3$.

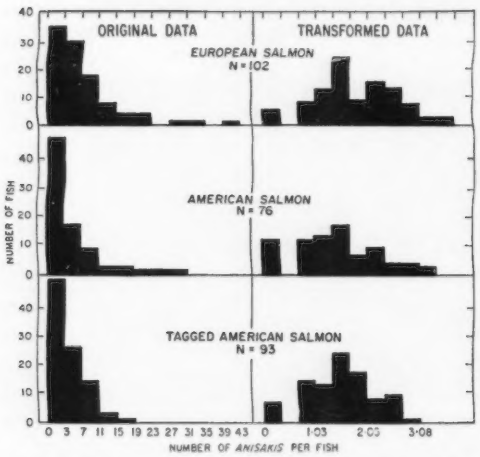
ORIGINAL DATA
TRANSFORMED DATA
EUROPEAN SALMON
N = 102
AMERICAN SALMON
N = 76
TAGGED AMERICAN SALMON
N = 93
NUMBER OF FISH
0 3 7 11 15 19 23 27 31 35 39 43 0 1·03 2·03 3·08
NUMBER OF ANISAKIS PER FISH

FIG. 8. Distribution of *A. simplex* in biochemically identified North American and European salmon and tagged North American salmon caught off Greenland in 1969. Transformed data are based on the equation $Y = \log_e (x + 1)$ (North America and Europe) and $Y = \log_e (x + \frac{1}{2}K)$ (tagged).

to identify the continental origin of adult Atlantic salmon caught on the high seas. Electrophoretic analyses of blood sera and liver tissues of salmon caught off West Greenland and in the Labrador Sea suggest that slightly less than half of the salmon caught in these areas in 1969 were of North American origin. Classification of the salmon is supported by a higher mean smolt age, a lower mean fork length, a lower mean number of *A. simplex* larvae per host, and a higher incidence of *E. crassum* tapeworms among North American salmon. The extremely low proportion of salmon classified as being of European origin in samples from Newfoundland (.007) indicates a reasonable degree of accuracy in classification of adult salmon caught on the high seas. The samples from the southern Labrador Sea are particularly interesting because they present the first evidence of European salmon so close to the North American continent. The electrophoretic characteristics of tissues from salmon, from the only known salmon producing river in Greenland (Kapisigdlit River), is not known. However, the contribution of this river to the salmon stocks off Greenland is extremely small (Neilsen 1961).

Observations on the smolt age composition of North American and European salmon in Greenland conform with previously published data (Templeman 1967) which indicate that the mean smolt age of salmon produced in North America is higher than that of those produced in England, Scotland, and Ireland. Also, the higher incidence of *E. crassum* in North American salmon conforms with Templeman's observation that, off Greenland, this parasite is more abundant in salmon with higher smolt ages than in those with lower smolt ages.

The characters used to distinguish the two types of salmon apparently reflect qualitative differences in their gene pools. With the possible exception of a single specimen from Newfoundland, no geographic overlap has been detected, and the two forms appear to be practically allopatric. Although both types mix on their oceanic feeding grounds, reproductive isolation is maintained by their strong homing instincts. These features and the application of Mayr's (1969) "75% rule" (page 190) to the phenotypic variations in protein structure noted in our samples support the view by Payne et al. (1971) that North American and European salmon represent

distinct subspecies. These authors recommended the names *S. s. americanus* and *S. s. europeus*, respectively, for the two forms.

Acknowledgments

The preliminary aspects of this investigation were undertaken in cooperation with the Swedish Salmon Research Institute, which provided the bulk of the fish analysed. Invaluable assistance was given by its coworkers and especially by its director, Dr Börje Carlin. Further samples were obtained through the assistance of Messrs Jerry Pratt and Alex Cowan, Department of Fisheries and Forestry, St. John's, Nfld., and Mr Alfred Meister, Atlantic Sea-Run Salmon Commission, State of Maine, whose help is gratefully acknowledged. The authors also gratefully acknowledge Dr Dag Møller, Fisheries Research Board of Canada, Biological Station, St. Andrews, New Brunswick, for providing blood samples and livers from the Miramichi River, and Mr Harry Ennis, St. John's, for allowing tissue sampling of salmon caught in his nets. Thanks are also due to Dr Arthur W. May, Fisheries Research Board of Canada, Biological Station, St. John's, Nfld., for valuable suggestions and criticism in the early stages of this work, and also to Mr Edward J. Sandeman for help with some of the statistical problems. Mr W. Henry Lear provided the samples collected from the Labrador Sea in 1970. Tagged Canadian salmon were obtained with the cooperation of the Godthåb Laboratory of the Grønlands Fiskeriundersøgelser through Messrs J. Møller Jensen and E. Hansen.

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Bioenergetics of a Sand Goby (*Gobius minutus*) Population

M. C. HEALEY[1]

University of Aberdeen
Culterty Field Station, Scotland

HEALEY, M. C. 1972. Bioenergetics of a sand goby (*Gobius minutus*) population. J. Fish. Res. Bd. Canada 29: 187–194.

This paper describes utilization of ingested energy by a population of sand gobies (*Gobius minutus*) in the Ythan estuary, Scotland, from November 1966 to March 1969. After metamorphosis (July) the gobies survived about 22 months, and their life could be divided into five stages: somatic growth (July–November); gonad growth (November–February); reproduction (February–June); more somatic growth (June–October); and further gonad growth (October–December). I calculated energy budgets for each stage from the relation:

$$0.8I = M + G$$

where: I = ingested calories; M = calories of metabolism; G = calories of growth.

Since I had measures of ingestion, growth, and routine oxygen consumption, I hoped to predict active metabolism by the energy ingested not accounted for in growth and routine metabolism. In fact, 0.8I either equalled the sum of growth and routine metabolism or was much too little to explain predicted expenditures for these parameters. Analysis of published feeding and growth studies in fish indicated that energy imbalances of this sort at low rations are general and that fish seem able to shunt more energy into growth when on a restricted ration than one would predict from studies of standard oxygen consumption. This result together with earlier analyses of Paloheimo and Dickie (1966) indicate that energy budgets for natural populations not based on accurate natural ingestion rates are at best only crude approximations.

HEALEY, M. C. 1972. Bioenergetics of a sand goby (*Gobius minutus*) population. J. Fish. Res. Bd. Canada 29: 187–194.

Nous décrivons dans ce travail l'utilisation de l'énergie ingérée par une population de gobies buhottes (*Gobius minutus*) dans l'estuaire de la Ythan, Ecosse, de novembre 1966 à mars 1969. Après la métamorphose (juillet), les gobies ont une durée de vie d'environ 22 mois, divisible en cinq stades: croissance somatique (juillet à novembre); croissance des gonades (novembre à février); reproduction (février à juin); croissance somatique additionnelle (juin à octobre); et nouvelle croissance des gonades (octobre à décembre). Nous avons calculé le budget énergétique de chaque stade à partir de l'équation:

$$0.8I = M + G$$

dans laquelle: I = calories ingérées; M = calories de métabolisme; G = calories de croissance.

Comme nous avions déjà mesuré l'ingestion, la croissance et la consommation routinière d'oxygène, nous espérions prédire le métabolisme actif à partir de l'énergie ingérée qui ne figure pas dans la croissance et le métabolisme de routine. De fait, 0.8I est soit égal à la somme des métabolismes de croissance et de routine, soit trop petit pour expliquer la consommation d'énergie prévue pour ces deux paramètres. L'analyse des données publiées sur l'alimentation et la croissance des poissons démontre qu'à de faibles niveaux de ration, un déséquilibre énergétique de cette nature se rencontre fréquemment. Soumis à des rations insuffisantes, les poissons semblent capables de détourner plus d'énergie vers la croissance que ne le portent à croire les études sur la consommation standard d'oxygène. Nos résultats, ainsi que ceux de Paloheimo et Dickie (1966), donnent à entendre que les budgets énergétiques de populations naturelles de poissons ne peuvent être tout au plus que des approximations grossières lorsqu'ils ne sont pas calculés à partir des taux naturels d'ingestion.

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[1]Present Address: Fisheries Research Board of Canada, Freshwater Institute, 501 University Crescent, Winnipeg 19, Man.

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ONE way to examine the organization of a population is to measure how it apportions the food energy it eats among its biological functions of growth, reproduction, and maintenance. Budgets of this sort are useful because they allow direct comparisons between populations regardless of their ecological niche. This paper describes an energy budget for the sand goby (*Gobius minutus* syn. *Pomatoschistus minutus*) and raises some general questions about the way fishes utilize food for growth and maintenance.

Deriving an energy budget for the sand goby was part of a general study of population ecology of the goby in the Ythan estuary, Aberdeenshire, Scotland (Healey MS 1969, 1971a, b). Young sand gobies of a particular year-class first appeared in my catches as late postlarvae in July each year and the last survivors disappeared 21–22 months later in March or April. The goby's life was divided into five stages characterized by a major biological activity; somatic growth from metamorphosis until November; gonad growth from November to February; reproduction from February to June; more somatic growth from June to October; and further gonad growth from October to December. Presumably the few surviving yearlings also bred after December, but I captured too few to make meaningful estimates. One aim was to develop separate energy budgets for each life stage. It seemed likely that seasonal changes in the way the goby dealt with the problem of energy balance might provide clues to the way the Ythan population was organized.

The general scheme within which I considered the energy budget was:

$$I = M + G + E \qquad (1)$$

where: I = ingested food energy; M = energy of metabolism; G = energy of growth (both somatic and gonadal); E = energy egested as feces and nitrogen excretion through gills and kidneys.

My approach was to measure ingestion and growth in the natural population; to estimate resting metabolism from laboratory measures of respiration rate; and to estimate egestion from published data. Because I had direct estimates of ingestion rate, a second aim was to estimate energy expended in activity and food processing by the fish in nature since these should equal ingested energy less that used for growth and resting metabolism, and that lost in feces and nitrogen excretion.

Estimating Elements of the Energy Budget Equation

INGESTION RATES

Estimates of ingestion rate were based on laboratory measures of digestion rate in relation to temperature and gut contents and field observations of daily and seasonal feeding activity. I used laboratory and field data to develop a simple model from which ingestion could be predicted from field measurements of low-tide gut contents and water temperature. Detailed derivation of the model is published elsewhere (Healey 1971a). Gobies fed on the rising tide but not on the falling tide so that their intake over a single tidal cycle was the difference between the amount in their guts at low tide, when feeding began, and high tide, when feeding stopped, plus the amount digested during the rising tide. Since there are two tidal cycles in a day, the daily intake is twice this amount. My laboratory measures of digestion rate in relation to temperature and gut contents allowed me to predict both high tide gut contents from those at low tide, and the amount digested during the rising tide. The resulting ingestion model was (Healey 1971a):

$$I = 0.28T + 1.10F + 0.67. \qquad (2)$$

where: I = the daily ingestion of a goby in milligrams dry weight; T = estuary temperature C; F = low tide gut contents of the goby in milligrams dry weight.

This model yielded estimates of ingestion rate from 0.67% to 15% body weight per day depending on season and size of fish, but for most of the goby's life the values were between 1 and 3% per day.

GROWTH

Wet weights of whole specimens, from twice monthly sampling, provided a measure of total growth. Gonads from a subsample of 24 fish each month provided a measure of gonad growth. Wet preserved weights were 5.17 ± 0.13 times dry weights (determined by drying fish to constant weight).

Most somatic growth occurred from July to November in underyearlings and from June to October in yearlings (cf. Swedmark 1958). The 1966–68 year-classes grew at different rates. Fish of the 1968 year-class weighed only 230 mg (dry weight) in November while those of the 1967 year-class weighed 560 mg. After their second growing season, however, the 1965–67 year-classes all weighed about 1200 mg.

Growth rates derived from size frequencies of successive samples from a population can be strongly biased if there is nonrandom immigration, emigration, or death of size classes. The goby population seemed to be restricted to the estuary, and I feel my sampling was adequate so that even if bias did occur, the size frequencies are still representative of the growth achieved by surviving members of the population.

Gonad growth paralleled somatic growth until November in underyearlings, but was more rapid from November to February (Healey 1971b). Gobies bred from February to June and females probably spawned twice. From February to June, therefore, gonad growth continued in females but not in males. After June relative gonad size was small until maturation for a second breeding season began in October.

Ripe females contained spawn equal to about 20% of their body weight. To calculate energy expenditure for ovary growth in underyearlings I have assumed

that each female spawned twice and each time released spawn equal to 20% of body weight. The first expenditure I assumed occurred between November and February and the second between February and June. Few fish survived to spawn as yearlings. A ripe yearling female contained spawn equal to about 15% of body weight. I assumed that yearlings only survived long enough to spawn once and that gonad growth for this spawning occurred between October and December.

Respiration

To establish a routine level of metabolism I measured the respiration rate of 43 gobies, using sealed vessel respirometry, between June 30 and August 1, 1969. Fish ranged in wet weight from 0.03–4.5 g and temperatures from 7–17 ± 0.5 C. I gave the fish 7 days to acclimatize to each temperature, then fasted them 24 hr before placing them individually into 1-liter conical flasks (200 ml flasks for the smallest fish), protected from light by black plastic shields. The fish were in the flasks 24 hr (during which time the water was aerated) before measurements began. I measured the respiration rate of each fish twice, then, discarded the fish.

Preliminary measures of respiration showed that water salinity over the range normally encountered in the estuary did not influence the respiration rate. Therefore, I made all measurements at 15‰ salinity. I used Winkler's method (Strickland and Parsons 1968) to determine the amount of O_2 in water samples taken from the flasks at the start and end of each measure of respiration rate. The drop in O_2 never exceeded 25% of the initial level, and in most cases was in the 15–20% range.

Multiple regression analysis of the measurements of O_2 consumption yielded the following equation:

$$\log Q = 0.791 \log T + 0.620 \log W - 1.615 \quad (3)$$

where: Q = O_2 consumption in ml/hr; T = temperature C; W = live weight of fish (g). This equation explained about 87% of the variation in O_2 consumption.

Winberg (1956) has suggested that at 20 C routine metabolism of all temperate zone fishes is adequately described by the relation:

$$Q = 0.3W^{0.8} \quad (4)$$

and that this relation can be extrapolated to other temperatures by Krogh's normal curve. At 20 C (3) reduces to:

$$Q = 0.27W^{0.62} \quad (5)$$

The weight exponent (0.62) differs significantly ($P < .05$) from Winberg's general exponent of 0.8.

On the basis of (3), gobies consumed between 1 and 13 ml of O_2 per day in routine metabolism in the estuary. Although no precise level of activity can be associated with measures of routine metabolism, the goby is a rather sedentary fish. Therefore, measures of routine metabolism probably do not differ much from standard metabolism, and most certainly represent metabolism at a very low level of activity. I feel that estimates of O_2 consumption made from (3) above can be regarded as reasonable estimates of maintenance metabolism of fasting gobies. Further, (5) indicates that my estimates of goby respiration are lower than average levels for fishes predicted by (4).

As measures of egestion I took Winberg's (1956) general estimate that 20% of ingested energy is voided as feces or lost in nitrogen excretion. More recent data (e.g., Pandian 1967; Warren and Davis 1966) indicate that this estimate is reasonable although perhaps a little high.

Calorific Equivalents

I used 5 cal/ml O_2 as suggested by Winberg (1956) and Paloheimo and Dickie (1966) to convert respiration measures to energy equivalents. Calorific values of food and fish I measured directly using an adiabatic bomb calorimeter.

The calorific equivalent for gobies, excluding guts and gonads, was 4.81 cal/mg dry weight (Table 1). Gobies ate a variety of organisms but the most common prey was *Corophium volutator* (Healey 1971a). To calculate the calorific value of an average goby meal I have assumed that the calorific values of the other food organisms (Table 1) were representative of the energy contents of animals in the goby's diet other than *C. volutator*, and that *C. volutator* made up 50% of the goby's diet. The calorific value of an average meal, therefore, was 3.79 cal/mg. I assumed the energy content of goby gonads was 6 cal/mg after Faustov and Zotin's (1967) value for demersal eggs.

The gobies I used to determine calorific equivalents were collected at different times of year. Although the sample was small, it indicated a seasonal variation in the energy content of gobies of about 0.4 cal/mg. Food organisms were all collected in spring 1969, allowing no measure of seasonal variation in calorific values of food. It seems unlikely that calorific values of foods would fluctuate more than the value of fish. The error introduced by not accurately measuring seasonal variations in the energy content of food and fish would, therefore, not alter the overall results by more than 5%.

Table 1. Energy equivalents for sand goby (*Gobius minutus*) and food organisms determined by bomb calorimetry.

Species	No. determinations	Dry wt (cal/mg)	Ash free (cal/mg)	Ash (%)
Gobius minutus	8	4.812	5.470	12
Corophium volutator	5	3.296	4.465	26
Nereis diversicolor	2	4.148	4.974	17
Neomysis integer	3	4.529	5.165	12
Crangon vulgaris	4	4.157	4.870	15

Energy Budgets

I calculated the energy budget for an "average" goby from each of those year-classes for which I had sufficient information (Table 2). Gobies showed quite different budgets during different stages of life history. Especially noticeable was that during periods of rapid somatic growth ingested energy was too little to account for growth and maintenance metabolism. At other stages the budgets balanced or small imbalances occurred that could easily be due to small errors in some of the approximations made. For example, imbalances disappear if the estimate of egested energy is reduced to 15% of ingested energy. This is not true of the imbalance during the periods of growth, since even if egestion is reduced to zero the imbalance remains.

At first, it seemed that the imbalance must arise through a large error in my estimate of ingestion. However, an examination of published experiments in which fish were fed known rations of 3% body weight or less and their growth rates measured indicate that perhaps this was not the case.

To date feeding and growth experiments with fish have not included direct studies of respiration. In those

Table 2. Energy budgets for individual gobies from each year-class for various stages in their life history.

Life stage	Dates	A cal ingested	B cal metab-olizable	C cal somatic growth	D cal		E cal available for respir'n B–(C + D)	F cal routine respiration	Cal available for activity E–F
					gonad ♂♂	growth ♀♀			
Year-class (1966)									
Gonad Matur. I	Nov.–Feb.	2012	1609	317	35	348	1101	1173	–72
Breed	Feb.–June	4582	3666	220	–	442	3225	2725	500
Growth II	June–Oct.	8802	7042	3974	–	–	3068	6813	–3745
Gonad Matur. II	Oct.–Dec.	3363	2690	–667	219	1097	2699	2558	141
Total		18759	15007	3844	254	1887	10093	13269	–3176
Year-class (1967)									
Growth I	July–Nov.	4002	3201	2611	–	–	590	2476	–1886
Gonad Matur. I	Nov.–Feb.	3353	2682	–472	58	580	2835	1501	1334
Breed	Feb.–June	5277	4221	360	–	627	3548	3057	491
Growth II	June–Oct.	8780	7024	3225	–	–	3799	7165	–3366
Gonad Matur. II	Oct.–Dec.	5932	4746	1546	210	1044	2573	2856	–283
Total		27344	21874	7270	268	2251	13345	17055	–3710
Year-class (1968)									
Growth I	July–Nov.	3245	2596	1136	–	–	1460	1663	–203
Gonad Matur. I	Nov.–Feb.	1487	1189	–76	26	255	1124	1178	–54
Total		4732	3785	1060	26	255	2584	2841	–257
All years									
Growth I	July–Nov.	3624	2899	1874	–	–	1026	2070	–1044
Gonad Matur. I	Nov.–Feb.	2284	1827	–77	40	394	1687	1284	403
Breed	Feb.–June	4930	3944	290	–	534	3386	2891	495
Growth II	June–Oct.	8791	7033	3600	–	–	3434	6989	–3555
Gonad Matur. II	Oct.–Dec.	4648	3718	440	214	1070	2636	2707	–71
Total		24277	19421	6127	254	1998	12169	15941	–3745

concerned with energy budgets metabolism was usually obtained by subtraction. In reviewing these studies I attempted to make the same comparisons as with the goby. That is, to compare energy available for metabolism, after growth and egestion are subtracted from ingestion, with an estimate of the maintenance metabolism derived from measures of O_2 consumption. For some species information on O_2 consumption was insufficient or unavailable. In these instances I used Winberg's (1956) general formulation (equation 4) corrected for temperature. Similarly, when calorific equivalents were not given I used conversion factors of 5 cal/mg dry weight or 1 cal/mg wet weight.

Some workers have noticed that when fish are starved, metabolic rate appears to go down. Winberg (1956) and Beamish (1964) both concluded that much of the observed reduction in metabolism may be a result of lower spontaneous activity in starved fish. Studies of weight loss in starved fish confirm that their metabolic rate is lower, but the reasons for this are not clear (Table 3). Some of the results in Table 3 may be biased by changing water balance and the utilization of high energy food stores in starving fish. Studies, such as that of Brett et al. (1969), in which these factors were taken into account make such simple explanations untenable. Also, their sockeye fingerlings were forced to swim at 1–2 lengths/sec throughout the experiment, so that a reduction in "spontaneous" activity seems an unlikely explanation for the apparent reduction in metabolism.

Starvation might be considered a special situation to which fish respond in a special way. However, studies of growth under conditions of restricted ration (3% body weight or less) indicate that metabolic rates below those expected from studies of standard or routine oxygen consumption are common (Table 4). Some of the results in Table 4 are clearly affected by errors in the assumptions. For example, those for chum salmon (*Oncorhynchus keta*) show energy deficits when growth is subtracted from metabolizable energy. In this case the food (*Calanus*) probably had an energy content greater than 5 cal/mg. Nevertheless, the results generally show that fish on restricted rations put less into metabolism than would

TABLE 3. Energy budgets for starved fish. From various sources.

Species	Source paper[a]	Temp (C)	A Days starved	B (cal/fish) start	C (cal/fish) end	(B–C)/A Daily cal metabolism	Daily cal routine respiration calculated	Respiration source paper[a]
Oncorhynchus keta (chum salmon)	1	14–16	42	1300	960	8.09	41.5	2
Oncorhynchus nerka (sockeye salmon)	3	1	83	9077	5723	40.4	60.2[b]	4,5
		5	99	8212	5337	29.0	88.0[b]	
		10	99	7657	3516	41.8	131.0[b]	
		15	99	8189	2561	56.9	184.2[b]	
		20	85	9561	2056	88.3	260.7[b]	
Salmo clarki (cutthroat trout)	6	8.5	20	3806	3374	21.6	45.4	2
Cichlasoma binoculara	6	20	14	6134	5815	22.8	56.2[c]	7,8
		23	14	6086	5718	26.3	76.6[c]	
		26	14	7052	6092	68.6	113.3[c]	
		29	14	6602	5849	53.8	142.0[c]	
		32	14	6506	5889	43.3	182.7[c]	
Apomotis cyanellus (green sunfish)	9	21	35	18350	16000	67.1	355.8	7
Pleuronectes platessa (plaice)	10	14	14	1750	1550	14.3	37.0	10
			26	1700	850	32.7	33.6	

[a]1. LeBrasseur (1969); 2. Winberg's (1956) average for salmonids; 3. Brett et al. (1969); 4. Brett (1964); 5. Brett (1965); 6. Warren and Davis (1966); 7. Winberg (1956); 8. Winberg (1961); 9. Moore (1941); 10. Edwards et al. (1969).
[b]Value for metabolism when swimming at 1.5 lengths per second. All others routine.
[c]Corrected for temperature adaptation.

TABLE 4. Energy budgets for fish on restricted rations. From various sources.

Species	Source paper[a]	Temp (C)	Days of expt.	Mean wt fish (g)	% Wt (fed/day)	A Metabolizable intake (cal/day)	B Growth (cal/day)	A–B Metabolism (cal/day)	Routine respiration (cal/day) calculated	Respiration source[a]
Esox lucius	11	Variable	300	106	0.35	376	28	348	528	7
(northern pike)	11	Variable	300	29	0.44	128	16	112	190	7
Oncorhynchus keta	1	14–16	56	0.88	3.3	27	15	12	35	2
(chum salmon)	1	14–16	56	1.22	3.3	35	36	–1	44	2
	1	14–16	56	1.03	3.2	28	24	4	37	2
Oncorhynchus nerka	3	1	83	6.69	1.48	98	18	80	120[b]	4,5
(sockeye salmon)	3	5	99	6.34	1.78	123	36	87	130[b]	4,5
	3	10	99	7.09	1.77	124	30	94	171[b]	4,5
	3	15	99	6.14	1.87	121	8	113	198[b]	4,5
	3	20	85	5.70	1.52	69	–14	83	353[b]	4,5
	3	1	83	6.86	3.03	217	29	188	123[b]	4,5
	3	5	99	7.94	3.44	329	80	249	155[b]	4,5
	3	10	99	9.76	3.42	359	100	259	244[b]	4,5
	3	15	99	10.12	3.51	385	82	303	293[b]	4,5
	3	20	85	6.86	3.00	185	4	181	340[b]	4,5
Apomotis cyanellus	9	21	98	17.5	1.2	168	0	168	359	7
(green sunfish)	9	21	?	17	1.45	198	94	104	343	7
Helioperca incisa	9	21	?	37.5	1.1	330	0	330	675	7
(bluegill)										
Perca flavescens	9	21	35	2.8	3.3	74	0	74	84	7
(yellow perch)		21	?	2.6	3.55	74	16	57	82	7
Salmo clarki	6	8.5	20	3.79	1.4	36	8	28	47	2
(cutthroat trout)	6	8.5	20	4.11	2.3	65	28	37	50	2

[a]Source numbers are the same as in Table 3, except 11, Johnson (MS 1960).
[b]Value for metabolism when swimming at 1.5 lengths per second. All others routine.

be predicted from measures of O_2 consumption of fasting fish. Especially interesting in this regard are the experiments of Brett et al. (1969), since O_2 consumption can be calculated on the basis of a known activity level. Still at a ration of 1.5% per day calculated O_2 consumption was greater than the energy available for respiration from the food, especially in the middle temperature range where growth was best. At a ration of 3.5% per day, however, metabolic expenditures from the feeding and growth study and respirometry agree quite well.

The use of a generalized equation for respiration rate in some of the examples given is open to criticism. Yet Winberg's generalized equation is an average so that when a wide range of fish types is examined one would expect the errors to fall on either side of the mean. All of the feeding and growth studies reanalyzed showed the same sort of energy imbalance, and in a number of instances it was possible to use published respiration studies for the same species to estimate oxygen consumption. The observed energy shortage at low rations, therefore, appears to be a real phenomenon, although how the fish compensate metabolically is unclear.

In the sand goby there was seasonal variation in budgets so that the apparent energy shortage during somatic growth was absent at other times of year. Warren and Davis (1966) obtained a similar result with sculpins in fall and winter (Table 5). In fall, when the water was warmer, sculpins grew better and showed a relatively greater energy imbalance than fish on a similar ration in winter.

Discussion

At our present stage of knowledge in population energetics the energy budgets I divised for the sand goby are possible. They fit into the general pattern of results from studies of feeding and growth of fishes, a pattern first noted by Edwards et al. (1969) in laboratory experiments with young plaice. The sand goby could be living and growing on the low rations predicted by my ingestion equation in spite of the suggested energy imbalance. If the budgets put forward in Table 2 are at all close to the truth then a number of questions are raised with respect to goby biology. The budgets indicate that gobies are living on a very restricted ration, yet my measurements of their available food supply (Healey 1971a) indicate that they are surrounded by an abundance of food.

Any ecological interpretation of the budgets in Table 2 is idle at this stage because the contradictions raised by my analysis of energy balance at low rations is only half the story. At higher rations the reverse occurs. That is, the energy available for metabolism after growth and egestion are subtracted from ingestion is much greater than one would predict that the fish would need from studies of O_2 consumption (Paloheimo and Dickie 1966). Given our present state of knowledge almost any level of ration I might have estimated for the goby would have been "reasonable" in the sense that it would have fit into the pattern of results derived from laboratory studies of feeding and growth.

Many assumptions are involved in the calculation of energy budgets, even when the basic data derive from relatively controlled laboratory studies. Yet it seems improbable that the suggested energy shortage at low rations is simply a result of cumulative errors in assumptions. Excesses of energy at high rations are less disturbing since it is possible to raise fairly simple hypotheses to account for energy loss (Warren and Davis 1966; Kerr 1971a, b, c). It is more difficult to imagine how fish would adjust their metabolism to channel more energy into growth and less into maintenance at low rations.

TABLE 5. Energy budgets for sculpins in fall and winter. (From data in Warren and Davis 1966.)

Temp (C)	Mean wt fish	Ration (% Wt/Day)	A Metabolizable energy (cal/day)	B Growth (cal/day)	A–B Metabolism	Routine O_2 consumption (cal/day)
			Fall			
11.6	1.35	0.63	7.24	1.45	5.79	19.89
11.6	1.39	1.27	14.78	5.11	9.67	20.33
11.6	1.56	2.00	26.11	11.74	14.37	22.29
			Winter			
6.9	1.55	0.35	4.73	–1.52	6.25	12.79
6.9	1.46	0.58	7.14	–0.64	7.78	12.17
6.9	1.54	1.06	14.01	2.77	11.24	12.07
6.9	1.70	1.60	23.24	4.84	18.40	14.36

One conclusion is clear, however. Until some of the problems raised by these contradictions are solved, energy budgets for natural populations of fishes must remain at best crude approximations.

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NOTES

Initial Studies on a Method of Algal Assay for Nutrient Parameters in Water

D. R. CULLIMORE AND A. MCCANN

Department of Biology
University of Saskatchewan, Regina Campus, Regina, Sask.

CULLIMORE, D. R., AND A. MCCANN. 1972. Initial studies on a method of algal assay for nutrient parameters in water. J. Fish. Res. Bd. Canada 29: 195–198.

A bioassay technique was outlined for estimating the impact of supplementation of the nutrients carbon, nitrogen, and phosphorus on algal growth. One of the main problems was the monitoring of algal growth using lengthy techniques of chlorophyll extraction with acetone. An alternative system involving filtration and reflectometric readings at 600 nm is described and found to be satisfactory when five readings were taken per filtered disk.

CULLIMORE, D. R., AND A. MCCANN. 1972. Initial studies on a method of algal assay for nutrient parameters in water. J. Fish. Res. Bd. Canada 29: 195–198.

Nous décrivons une technique d'analyse biologique pour mesurer les effets d'un supplément des éléments nutritifs C, N, et P sur la croissance des algues. Le contrôle continu de la croissance des algues par de longues méthodes d'extraction de la chlorophylle à l'acétone pose un problème important. Nous décrivons une méthode alternative impliquant la filtration et la lecture au réflectomètre à 600 nm, méthode adéquate lorsqu'on fait cinq lectures par disque filtré.

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STUDIES of eutrophication in freshwater bodies have been largely limited to nutrient levels found within the system. Studies have been initiated to evaluate methods for estimating the nutrient concentrations in water by algal assays (Provasoli 1969; Sakamoto 1971). In the United States a Provisional Algal Assay Procedure (PAAP) is being investigated as a standard test method (Bueltman 1969). The major advantage of this analytical approach is that the algae used may differentiate the fractions of nitrogen and phosphorus that may be assimilated during eutrophication more precisely than existing chemical methods. Similar procedures have been suggested for estimating available soil nutrients for plant growth using algae as the plant indicator (Cullimore 1966). In studying levels of algal nutrients in water, two basic systems, "dilutive" and "supplementive", may be adopted. In the "dilutive" system, the given water sample for assay is diluted with a known quantity of distilled water, and varying selections of the nutrients returned to their original level. Thus, regimes are created where nutrients singly or in combination with others may be evaluated for their ability to affect algal growth. In the "supplementive" system, selected combinations of nutrients are added to the water samples and the influences of this on algal growth are related to the concentrations. In either case, the algae used may be indigenous from the water sample, or may be augmented or replaced by pure cultures known to form the major component of the "blooms." In this study, a method of soil bioassay has been modified and adapted to assay for carbon, nitrogen, and phosphorus in water. The water studied is from lakes within the Qu'Appelle River basin that have high nutrient and salt concentrations and eutrophy (Hammer 1969). Only the "supplementive" system of assay has been used.

Methods — Each assay consisted of 125 different combinations of carbon (as glucose), nitrogen (as ammonium nitrate), and phosphorus (as dipotassium hydrogen phosphate). Each element was used at five concentrations, and "paired off" with all other concentration combinations of the other two nutrients. Concentrations used were: (carbon, ppm), 0, 12, 24, 48, 96; and (phosphorus or nitrogen, ppm), 0, 1.5, 3, 6, 12. Each individual nutrient combination was carried out in an 18 × 18 × 18-mm compartment of a 25-compartmented sterile plastic container. The nutrients were aseptically added to each compartment as a pre-prepared 1-ml solution at 400% final concentration, with

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3 ml of freshly collected lakewater to give the final concentrations. For pure cultures, the water sample was preserved by slow freezing to –10 C. Prior to assay, it was thawed and membrane-filtered. This removed all indigenous algae and therefore prevented interference with the assay except from some nutrients that may have been released from the disrupted cells. Pure cultures of algae were grown on "George's" agar that consisted of (g/liter): Difco proteose peptone, 10; potassium nitrate, 2; dipotassium hydrogen phosphate, 0.2; magnesium sulphate, $7H_2O$, 0.2; and ferric citrate, 0.00035. Incubation was at 22 C, illuminated by Westinghouse Co. "Plant-Gro" fluorescent tubes. The inoculum was prepared by washing algae off the agar surface with sterile distilled water, and standardizing by chlorophyll extract; 0.1 ml was inoculated into each compartment. Incubation of the assays was at 22 ± 1 C illuminated by "daylight" fluorescent tubes. Algal growth first appeared after 5 days, peaked at 10–14 days, after which senescense occurred.

Algal growth was estimated by an extraction procedure using 90% acetone, and by a reflectometric method. In the extraction procedure, all 4 ml of the culture were filtered through a Whatman No. 2 filter paper. The residue and paper were shredded and extracted with 5 ml 90% acetone at 4 C for a minimum of 12 and maximum of 72 hr. Absorbtion values were then read at 630, 642.5, 670, and 750 nm. Chlorophyll *a* (ppm) was estimated by the formula:

$$\text{chl. } a = (15.6 \times \text{C.O.D.}_{670} - 2 \times \text{C.O.D.}_{642.5} - 0.8 \times \text{C.O.D.}_{630}) \frac{5}{0.004}$$

where C.O.D. represents the original optical density at the wavelength indicated beneath minus the optical density at 750 nm.

In the reflectometric procedure, the 4-ml culture was filtered under negative pressure down a 1-cm diameter brass tube onto a 4.25-cm diameter Whatman No. 2 filter paper. A plexiglass holder held the brass tube in place. For the algal residue to appear as an even deposit 1.1 cm wide, thus eliminating creeping of the residue, the culture had to be slowly added drop by drop down the tube. Once removed, the filter papers were air dried at room temperature between sheets of bibulous paper. Density of the algal residue was measured using the reflectometric attachment to a Bausch and Lomb Spectronic "20", at 600 nm with slit aperture of 3 × 2 mm. This wavelength was selected since it lay between the optical wavelength peaks for the chlorophylls and for phaecophycin and would therefore give a better indication of total algal growth expressed by the pigmentation. The algal residue zone was next cut out of the filter paper, shredded, homogenized, and extracted using 90% acetone.

For the assays, samples were collected from the top 1-m zone in lakes Eyebrow and Pasqua, Saskatchewan. Pollution parameters were determined at the University's Water Quality Research Laboratory. Results (ppm, unless otherwise indicated) for Eyebrow and Pasqua lakes respectively were: *p*H, 8.9, 8.1; conductivity (μ mosmol/cm) 2.4, 1.9; turbidity, 20, 12; nitrate nitrogen, 0.49, 0.46; total nitrogen, 1.25, 3.57; total phosphorus, 0.76, 1.08; total inorganic phosphorus, 0.80, 0.98; dissolved oxygen, 17.74, 12.18; B.O.D. 5.07, 1.73; total organic carbon, 25, 25; inorganic carbon6, 0, 41; total hardness, 358.4, 859.1; total alkalinity, 373.5, 311.4; chlorophyll *a* not detectable.

Comparisons of reflectometric readings with the extraction procedure were also made using pure cultures of algae. These were obtained from the National Collection of Algae and Protozoa, Cambridge, England. The algae were cultured on plates of "George's" agar, washed off with sterile distilled water, then filtered and extracted as described above.

Results and discussion — The bioassay results are shown in Fig. 1. Comparisons of the reflectometric data with equivalent extraction data for both individual wavelengths and chlorophyll *a* are given in Table 1 for both the indigenous and uni-algal cultures.

From Fig. 1, it is apparent that algae responded to the addition of phosphorus to a much greater ex-

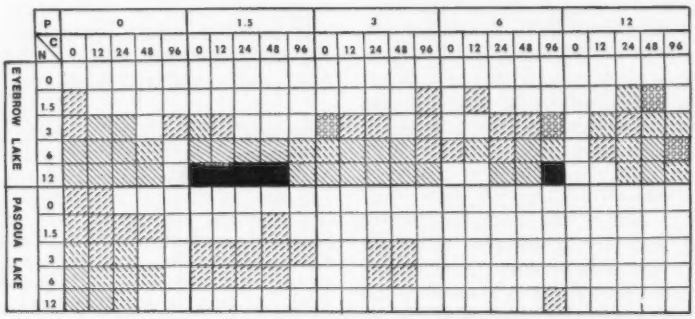

FIG. 1. Influence of concentrations (ppm) of phosphorus, carbon, and nitrogen on the growth of algae given as ppm chlorophyll *a*. Blank, 0 ppm; dots, 1–10; discontinuous line rising left to right, 11–50; discontinuous line falling left to right, 51–100; continuous line falling left to right, 101–500; and solid, > 500 ppm.

TABLE 1. Comparison of the extraction and reflectometric methods for measuring algal growth by chlorophyll content. Two columns represent *x* and *y* axes for a linear regression analysis of the recorded features for five different algae. For each regression the tangent (*b*), intercept (*a*), and correlation (*r*) is given.

		Chlamydomonas terricola 11/37[a]			*Chlorella vulgaris* 211/11a			*Haematococcus lacustris* 34/1h			*Scenedesmus quadricauda* 276/4a			*Spongiochloris excentrica* 280/1		
X	*Y*	*b*	*a*	*r*	*b*	*a*	*r*	*b*	*a*	*r*	*b*	*a*	*r*	*b*	*a*	*r*
Cell no.	Extractable chlorophyll *a*	0.56	−0.07	0.99	0.29	−1.07	1.00	0.22	−0.20	0.89	0.36	−0.26	0.93	0.33	−0.09	0.86
Cell no.	Central reflectometer reading of disk	0.22	−0.01	0.98	0.32	−0.01	0.99	0.99	−0.01	0.67	0.18	−0.01	0.95	0.32	0.06	0.69
Cell no.	Mean of 5 reflectometer readings per disk	0.23	−0.01	0.99	0.31	−0.01	0.99	0.09	−0.01	0.82	0.18	−0.01	0.96	0.44	0.04	0.89
Central reflectometer reading of disk	Extractable chlorophyll *a*	2.48	0.03	0.97	0.86	−0.09	0.98	0.50	0.06	0.63	1.49	−0.13	0.87	0.19	0.18	0.25
Mean of 5 reflectometer readings per disk	Extractable chlorophyll *a*	2.40	−0.04	0.98	0.93	−0.11	1.00	0.82	0.03	0.57	1.70	−0.18	0.83	0.57	−0.03	0.70

[a]Strain number: National collection of Algae and Protozoa, Cambridge, England.

tent in Eyebrow than in Pasqua Lake, showing extensive growth up to supplementive concentrations of 12 ppm phosphorus. Pasqua Lake supported significant algal growth only with a low phosphorus regime, indicating an adequate amount of phosphorus in the water for algal growth. Reference to the chemical data shows that Pasqua had high levels of phosphorus, 42% more in total and 22% more in the inorganic form. Carbon concentrations had no significant effect on the algal growth in either Pasqua or Eyebrow lakewater. Nitrogen, however, had a stimulatory effect on algal growth in both lake samples. In Eyebrow, a continuing response occurred above an initial supplementation of 3 ppm reaching a maximum at 12 ppm with a 1.5 ppm supplementation of phosphorus. Response to nitrogen in Pasqua lakewater was less pronounced. Pasqua Lake samples upon analysis contained 3.6 ppm total nitrogen, whilst Eyebrow possessed only 1.3. The algal response to both nitrogen and phosphorus was most striking and would indicate that this assay method should be more completely evaluated as a potential analytical test to assay water for available nutrient content. Further studies are being undertaken to evaluate the statistical validity of such a system and the potential value of this method for estimating the influence of micro-nutrients such as magnesium, iron, and molybdenum.

Coupled to any system of rapid monitoring of algal growth is the need for an efficient system of estimating this, directly or indirectly. The chlorophyll *a* extraction method (Table 1) was extremely accurate when compared to cell numbers for pure cultures of algae. The poorest regression correlations of 0.89 and 0.86 were obtained for *Haematococcus lacustris* and *Spongiochloris excentrica*, respectively. Where the reflectometric technique was used with a central disk reading only, poor correlations (0.67 and 0.69, respectively) were obtained for the same algal cultures. All the other algae gave correlations of 0.95 or better which improved even more when the mean of five readings across the disk were taken. For the two strains giving poorer correlations, taking the mean of five readings improved the correlation to 0.82 and 0.89, respectively. From those results, it would appear that the reflectometric method using five readings would have a similar accuracy when using standard curves to the acetone extraction method for monitoring algal growth. Direct comparison of the two methods showed extremely high agreement for *Chlamydomonas terricola* and *Chlorella vulgaris* ($r = 0.98$ and 1.00, respectively), moderate agreement for *Scenedesmus quadricauda* ($r = 0.83$), and poor for *H. lacustris* and *S. excentrica* ($r = 0.57$ and 0.70, respectively). The latter were poorer because these cultures did not extract so completely, and did not spread over the filter paper so evenly, producing a greater variation in reflectometric readings. This method would, however, provide a useful alternative to extraction procedures, and studies are underway to evaluate its usefulness in this regard.

Acknowledgments — We wish to acknowledge the financial assistance of the Saskatchewan Research Council through direct funding of this project. Also the National Research Council of Canada for the financial support of a mobile laboratory used in this study.

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Exposure Times Necessary for Antimycin and Rotenone to Eliminate Certain Freshwater Fish

PHILIP A. GILDERHUS

U.S. Fish and Wildlife Service
Fish Control Laboratory, La Crosse, Wis. 54601, USA

GILDERHUS, P. A. 1972. Exposure times necessary for antimycin and rotenone to eliminate certain freshwater fish. J. Fish. Res. Bd. Canada 29: 199–202.

In laboratory flowing-water troughs exposure required to induce 100% mortality, regardless of time to death for antimycin and rotenone against selected freshwater fish species was determined. Carp and white suckers required shorter exposures to antimycin (6 hr) than to rotenone (18–24 hr) at field-use concentrations of 5 and 50 ppb respectively. Bullheads were killed by 3–10 hr exposure to 100–250 ppb rotenone at 17 C or higher. However, the long exposure time necessary in colder water (25 hr at 100 ppb in 12 C water) made elimination of bullheads with rotenone difficult in cold seasons. Exposure time was influenced more by water temperature than by the toxicant concentration. The effects of rotenone were often reversible even after fish had been on their sides in the toxicant solution for 4–5 hr but irreversible for antimycin after fish showed the first signs of distress.

GILDERHUS, P. A. 1972. Exposure times necessary for antimycin and rotenone to eliminate certain freshwater fish. J. Fish. Res. Bd. Canada 29: 199–202.

Nous avons mesuré le temps d'exposition à l'antimycine et la roténone requis pour causer la mortalité totale, sans égard à la longueur de l'agonie, de certaines espèces de poissons d'eau douce. Les expériences se sont poursuivies en laboratoire dans des bacs pourvus d'eau courante. Les grandes espèces, telles que catostomes noirs communs et carpes, requièrent une exposition plus courte à l'antimycine (6 h) qu'à la roténone (18 à 24 h) aux teneurs en usage sur le terrain de 5 et 50 ppb respectivement. Les barbottes meurent après exposition de 3 à 10 heures à 100–250 ppb de roténone à 17 C ou plus. Toutefois, la nécessité d'une exposition plus longue dans des eaux plus froides (25 h à 100 ppb à 12 C) rend plus difficile l'élimination des barbottes à la roténone pendant la saison froide. La température de l'eau, plus que la concentration de l'agent intoxicant, affecte le temps d'exposition. Souvent, les effets de la roténone sont réversibles, même si le poisson a été sur le côté durant 4 à 5 heures. Par contre, les effets de l'antimycine sont irréversibles dès qu'apparaissent les premiers signes de détresse chez le poisson.

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ANTIMYCIN and rotenone, the two fish toxicants registered in the United States, are commonly used to reduce or eliminate populations of undesirable freshwater fish. Some stream reclamations using toxicants have failed (Barry and Larkin 1954; Binns et al. 1964; Herrig 1964; Lennon et al. 1970), probably due to the fish not being exposed long enough to the chemical. Length of exposure is as important as concentration in contributing to a lethal dose of a toxicant. In streams where a chemical moves past the fish and in standing bodies of water where rapid dilution or degradation is likely to be a problem, length of exposure is a critical factor.

Several authors have reported laboratory studies on time to death of fish exposed to rotenone (Gersdorff 1930; Leonard 1939; Burdick et al. 1955; Bassett 1956). Apparently, Lennon and Parker (1959) did the only study where time to death for individual species in the water to be treated was determined prior to treatment. However, time to death in a solution of toxicant and length of exposure necessary to induce complete mortality are different entities, the latter being much shorter.

If treatments of streams are designed on the basis of time to death, most streams will be under treatment longer than necessary. Effective and efficient reclamations must be based on the proper balance between concentration and exposure time.

This study with antimycin and rotenone was conducted to define the effective contact time (ECT), which for a toxicant, is the length of exposure necessary to induce 100% mortality of target animals with a given concentration, regardless of the time it takes them to die.

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Materials and methods — Target species were carp (*Cyprinus carpio*) and white suckers (*Catostomus commersoni*). Other species tested were black bullheads (*Ictalurus melas*), green sunfish (*Lepomis cyanellus*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), and rainbow trout (*Salmo gairdneri*). Size ranges are given in Table 1.

Groups of five to 10 fish were exposed for each of several periods of time at each concentration. The fish were exposed to the toxicants in a stainless steel trough 3.75 m long, 0.34 m wide, and 0.34 m deep, divided into five equal sections by perforated aluminum plates. The water was kept at 0.12 m deep by a standpipe and supplied from a constant-head box at 28.6 liters/min. Time of travel from inlet to outlet was 4.5 min.

Laboratory well water was used for all tests at 12 C. For tests at 17 and 22 C, enough heated city water was piped into the headbox to raise the 12 C well water to the desired temperature. The ranges of some water quality parameters of the water supplies were (well water with city water values in parentheses): *p*H 7.5–8.0 (7.4–8.2), total alkalinity (mg/liter) 223–262 (209–250), and total hardness (mg/liter) 238–371 (289–340). The water contained about 8.5 mg/liter of dissolved oxygen at the outlet.

Carp, white suckers, black bullheads, and green sunfish were exposed at 12, 17, and 22 C. Species killed by shorter exposures were tested only at 12 C since they would be eliminated along with those more resistant species.

Fish were acclimated and held for recovery in a concrete tank supplied with aerated well water. The fish for each exposure time were kept in a separate screen cage. Water temperature was regulated by a steel immersion heater and a circulating pump in the tank. Fish exposed at 12 C were acclimated for 24 hr. Those exposed at 17 C were acclimated for 24 hr and the water temperature was raised from 12 to 17 C during the first 6–8 hr of the 24. Those exposed at 22 C were tempered during a period of 36 hr and were usually held an additional 24 hr at that temperature.

The fish were moved to the testing trough an hour before the addition of toxicant began. After a selected number of hours in the toxicant, each group was returned to the freshwater tank and held until 96 hr after the beginning of exposure.

The chemicals[1] used were Fintrol Concentrate, a liquid formulation containing 10% antimycin and Noxfish, a liquid formulation containing 5% rotenone. The concentrations (active ingredient) used, 5–10 ppb of

[1]Reference to brand names does not imply Bureau endorsement to the exclusion of similar products.

TABLE 1. The effective contact time (ECT) to eliminate selected species of fish with antimycin and rotenone.

Species (length, *mm*)	Water temp (*C*)	ECT in hr for Antimycin (*ppb*)		Rotenone (*ppb*)		
		5	10	50	100	250
Rainbow trout (64–124)	12	2	1	2	–	–
Carp	12	6	6	24	18	16
(127–305)	17	3	3	10	9	5
	22	2	1	–	5	–
Carp	12	–	6	–	–	–
(41–53)						
White sucker	12	6	4	18	17	9
(119–264)	17	2	1	9	5	3
	22	1	0.5	–	1	–
Black bullhead	12	–	–	–	25	>24[a]
(178–250)	17	–	–	–	10	3
	22	–	–	–	8	–
Black bullhead	12	–	–	–	21	15
(56–66)						
Green sunfish	12	11	10[a]	–	8	1
(30–56)	17	4	1.5	–	–	–
	22	1	0.5	–	0.5	–
Largemouth bass	12	13[a]	6	8	–	1
(64–127)						
Yellow perch	12	4	2	–	0.5	–
(45–74)						

[a]Estimated from exposure where some fish survived.

antimycin and 50–250 ppb of rotenone, are those generally used in field applications. The toxicants were mixed with water so that 3–6 liters/hr of the stock solution, applied to the inlet, produced the proper concentration. The stock solutions were injected with an electric fuel pump, adjusted to an accuracy of ±4%.

Results — Rainbow trout and yellow perch were very sensitive to both chemicals, the ECT's being from 1 to 4 hr (Table 1). The short ECT's make them easy to eliminate in the presence of more resistant target species.

Among the species studied, carp and suckers are the most likely to be the target fish in flowing water. The ECT for 5 ppb of antimycin on these species was somewhat shorter than that for 250 ppb of rotenone at 17 and 22 C, and much shorter at 12 C. At 17 C both species were eliminated by 3 hr of exposure to 5 ppb of antimycin or 5 hr of exposure to 250 ppb of rotenone. The ECT's for those concentrations to eliminate both species at 12 C were 6 hr for antimycin and 16 hr for rotenone.

No tests were conducted with antimycin against black bullheads because Walker et al. (1964) documented that it is not very effective against species of the family Ictaluridae. Rotenone was fairly effective on bullheads at temperatures above 17 C, but at 12 C, they must be exposed to 100 ppb for at least 25 hr, which ECT is too long to be practical for stream treatments.

The ECT's for green sunfish were in the same range for both toxicants. Largemouth bass were substantially more resistant to antimycin (13 hr) than to rotenone (8 hr) at minimum field-use concentrations. Against the more sensitive species the ECT for 50 ppb of rotenone was comparable to or shorter than the ECT for 5 ppb of antimycin, whereas against the more resistant carp and suckers the ECT for 5 ppb of antimycin was shorter than that for 250 ppb of rotenone.

Increasing the concentration of toxicant did not have as much effect on the ECT as did raising the water temperature. Considering all the data, doubling the concentration shortened the ECT's for antimycin by an average of 38.3% and for rotenone by 36.6%. Increases of 5 C decreased the ECT's by an average of 61.7 and 60.9% for antimycin and rotenone, respectively.

Discussion — This study revealed some consistent patterns concerning the reversibility or irreversibility of toxicity in relation to the obvious symptoms of toxicity. No fish survived after losing equilibrium due to exposure to antimycin. There appears to be a point, while they are still swimming, at which they have assimilated an irreversible, lethal dose. In contrast, the ECT for rotenone was generally reached only after the fish had been incapacitated in the toxicant solution for 1–5 hr. Often, fish that had been on their sides in rotenone solution for up to 4 hr recovered later in fresh water. This is in direct conflict with some authors (Leonard 1939; Bassett 1956) who stated that no fish could survive after losing equilibrium due to exposure to rotenone.

Antimycin appears to be more suitable for stream treatments when carp or suckers are target species. It has a short ECT and due to its apparent irreversibility fish that later find their way into untreated water are likely to die anyway.

The length of time a given concentration of toxicant must be maintained at any given point in a stream is logically the effective contact time for the most resistant target species. Thus, the ECT's for the target fish and the flow and dilution patterns for a stream must be known prior to treatment. Furthermore, the ECT may be an important consideration in standing water. For example, under conditions of highly alkaline or high *p*H waters, it is possible that the toxicant will degrade before the ECT is reached. Marking (1970) lists the half-life of biological activity of antimycin as 9.7 hr at *p*H 9, 4.6 hr at *p*H 9.5, and 1.5 hr at *p*H 10. This indicates that at some combinations of high *p*H and low water temperature it could be impossible to obtain an adequate exposure at reasonable concentrations.

The proper concentration and exposure time for a reclamation with toxicants cannot be chosen arbitrarily without some knowledge of each for the target species in the target water. Therefore, it is highly advisable to use stream-side bioassays to determine the appropriate concentration and ECT. The ECT's presented here can serve as guidelines for selecting exposure times to be used in field bioassays or short stream treatments.

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Change in Body Weight Caused by Handling and Exercise in Fish[1]

E. DON STEVENS

Department of Zoology
University of Hawaii, Honolulu, Hawaii 96822, USA

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Either handling or exercise cause an increase in body weight in fish acclimated to fresh water, and a decrease in body weight in fish acclimated to sea water.

STEVENS, E. D. 1972. Change in body weight caused by handling and exercise in fish. J. Fish. Res. Bd. Canada 29: 202–203.

La manipulation ou l'exercice entraîne un accroissement de poids corporel chez les poissons acclimatés à l'eau douce, et une diminution chez les poissons acclimatés à l'eau salée.

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WHILE studying the transport of oxygen and carbon dioxide across fish gills, it was predicted that the rate of water and salt transport should increase across the respiratory interface during exercise (Randall et al. 1967). Subsequently, I showed that 2 min of severe exercise in trout caused a small but consistent increase in body weight (Stevens 1968). The present project was carried out to demonstrate that even handling can effect significant changes in body weight and that these osmotic movements of water should be taken into consideration by those taking blood samples by any method which may excite the fish.

Methods — Ten *Tilapia mossambica* weighing 0.5–3.5 g were caught and maintained in fresh water at 22–24 C. Fish were fed frozen brine shrimp three times per week. Each fish was kept in a separate container in 1 liter of aerated water.

Two procedures were employed: handling and exercise. A fish was "handled" by quickly netting it from its container, blotting it once on a paper towel, weighing it on a Mettler balance, transferring it to a cylindrical aquarium and leaving it there 4 min, netting it again, blotting, and weighing it a second time. A fish was "exercised" by treating it identically, except when placed in the cylindrical aquarium, the fish was forced to swim at approximately 30 cm/sec (tail-beat frequency 180–200/min) for the 4-min period. Each fish was "handled" individually, and 1 week later the same fish were "exercised" individually. The same fish were then acclimated to salt water over a 1-week period. The effects of handling and exercise were repeated on the same fish now acclimated to sea water.

Results — Almost invariably, handling or exercise under these conditions evoked a color change: dark vertical bars appeared on the previously grey-silver sides. The color change was completely abolished within 5 min of a single injection of

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phenoxybenzamine in saline (IP). Either handling or exercise caused an increase in body weight with fish acclimated to fresh water, but caused a decrease in body weight in the same fish acclimated to salt water (Fig. 1).

Discussion — The color change is indicative of either stimulation of the sympathetic nervous system or an increase in the level of circulating catecholamines since it was abolished by the adrenergic blocking agent phenoxybenzamine. This observation is in agreement with the results of Scheline (1963) who demonstrated an inhibition of chromatophore pigment concentration by epinephrine in a wrasse after treatment of the scales with phenoxybenzamine.

Both handling and exercise cause an increase in oxygen uptake in fish (Fry 1971). In salmonids the elevated oxygen uptake is accomplished in part by an increase in the transfer factor of the gills (Randall et al. 1967). From their analysis it is likely that the transfer factor increases in other fish during periods of elevated oxygen uptake also. That is, the effective exchange area of the gills is increased. The respiratory interface is also permeable to water, and thus the increase in effective exchange area results in an increase in the osmotic movement of water. In fresh water, the water moves down the osmotic gradient into the animal; in salt water, the water moves down the osmotic gradient out of the animal. Although the osmotic gradient is much greater for fish in salt water than in fresh water, the percent change in body weight was approximately the same. This may be due to the fact that saltwater acclimated fish drink more to compensate for the constant osmotic loss.

The effect of handling on the movement of water in fish should be recognized especially by anyone taking blood samples by any method that may excite the fish and thus elevate oxygen uptake and water movement. The fact that the water movement may dilute or concentrate blood constituents should be taken into consideration.

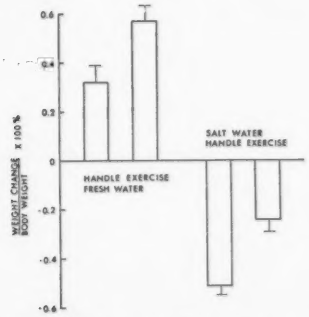

FIG. 1. The percent change in body weight of *Tilapia mossambica* occurring as a result of handling and exercise. The same fish were used for each of the four conditions. Values are means ±SE.

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Virulence and Persistence of Rough and Smooth Forms of *Aeromonas salmonicida* Inoculated into Coho Salmon (*Oncorhynchus kisutch*)

DOUGLAS P. ANDERSON

Bureau of Sport Fisheries and Wildlife
Western Fish Disease Laboratory, Seattle, Wash. 98115, USA

ANDERSON, D. P. 1972. Virulence and persistence of rough and smooth forms of *Aeromonas salmonicida* inoculated into coho salmon (*Oncorhynchus kisutch*). J. Fish. Res. Bd. Canada 29: 204–206.

Virulent isolates of *Aeromonas salmonicida* showed a majority of smooth colonies, while the attenuated isolates displayed mostly rough colonies. A lesion occurred at the site of inoculation when one of the rough forms was inoculated into yearling coho salmon, but few mortalities were recorded even though the rough forms were readily recovered from both the lesion and the kidney. The fish inoculated with the same dosage of smooth forms all died within 96 hr of inoculation.

ANDERSON, D. P. 1972. Virulence and persistence of rough and smooth forms of *Aeromonas salmonicida* inoculated into coho salmon (*Oncorhynchus kisutch*). J. Fish. Res. Bd. Canada 29: 204–206.

Les isolats virulents d'*Aeromonas salmonicida* se présentent en grande partie sous forme de colonies lisses, alors que les isolats de virulence atténuée forment surtout des colonies rugueuses. Lorsque la forme rugueuse est inoculée à des saumons coho d'un an, il se produit une lésion au point d'inoculation. Par contre, il n'en résulte qu'une faible mortalité, même si les formes rugueuses sont aisément récupérées de la lésion aussi bien que du rein. Tous les poissons soumis au même dosage de la forme lisse meurent en moins de 96 heures après inoculation.

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SOME of the isolates of *Aeromonas salmonicida*, the etiological agent of furunculosis in fish, stored at this laboratory show lower virulence than recent isolates from hatchery epizootics. The attenuation, or the loss of virulence, of this bacterium when kept in culture has been noted by Snieszko (1970). Duff (1937) earlier described dissociate forms of the bacterium: smooth (S), rough (R), and minute (G) colony types. He linked the smooth form to virulence in the goldfish (*Carassius auratus*).

This report describes the types of colonies formed by *A. salmonicida* as they were taken from the storage file and plated on trypticase soy agar (TSA). The different colonial morphologies were characterized, and the bacteria inoculated into yearling coho salmon (*Oncorhynchus kisutch*) to investigate virulence, penetration, and persistence in the fish.

Materials and methods — The following five cultures of *A. salmonicida* were selected for study: No. 2, originally isolated from cutthroat trout, Leavenworth, Washington, 1961; No. 34, from coho salmon, the Snake River area in Oregon, 1965; No. 95, from coho salmon, Issaquah, Washington, 1968; No. 97, from brown trout, Maple, Ontario, 1968; and No. 111, from eastern brook trout, Winthrop, Washington, 1970.

Each of these isolates except No. 111 had been stored on Brain-Liver-Heart Semisolid (Difco), and transferred every 6 months to fresh medium. For the experiments, a loopful of the culture was spread onto a TSA plate and incubated at 17 C for 48 hr. The resultant colonies were classified, and were later used for the in vivo tests. Colonial morphology differences in *A. salmonicida* are subtle. In every case a binocular-dissecting microscope was used in classifying and sampling individual colonies.

A motility test and biochemical tests, including Kovac's oxidase, Hugh and Leifson oxidation-fermentation, and glucose utilization, were carried out on each of the five isolates and their rough and smooth forms.

Bacterial suspensions for inoculation were made by first harvesting the colonies from the TSA plates with physiological saline, and washing once by centrifugation. The pellet was resuspended in saline and diluted to 40% transmittance at 650 mμ measured in a Hitachi Perkin-Elmer spectrophotometer Model 139. The bacterial population density of this dilution was checked on a Petroff-Hauser bacterial counting chamber. The

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number of bacteria at this level (0) was approximately 2×10^{12} cells/ml.

Coho salmon averaging 11.5 g were brought to the laboratory from the Skykomish Washington State Hatchery and kept on dechlorinated Seattle city water at a regulated temperature of about 20 C. These fish had no known history of furunculosis, and the controls showed no unexplained mortalities throughout the experiments.

In the first experiment, virulence tests were performed by comparing the LD50s for each of the five isolates and their respective forms. Ten yearling coho salmon were inoculated at each tenfold dilution of the standard bacterial suspension. An end point of 5 days was chosen for determining cumulative mortality. Probit analysis was used to find the LD50 dose.

The second experiment was designed to investigate the penetration and/or persistence of the R and S forms. A group of 60 fish was inoculated with No. 2 R, and a similar group with No. 2 S. The inoculum dosage for each group was calibrated at 1.2×10^9 bacteria from the dilution standard. This dosage was known from the previous experiment to be an LD100 for the S forms, but nonlethal for the R forms. Ten fish were taken from each group at 2, 24, 48, 72, 96, and 120 hr after inoculation, and sampled by placing an inoculation loopful of the subcutaneous lesion debris and a kidney smear on a TSA plate.

For all work the fish were inoculated subcutaneously craniad to the dorsal fin. Mortalities were recorded and sampled for the presence of bacteria in the kidneys and lesions.

The pathogenicities of the R and S forms of each isolate were tested on tissue culture. Cover-slip cultures of fathead minnow cells were prepared in 2-oz French square bottles. After a monolayer was obtained, the cells were rinsed three times with Earle's basal salt solution, then 1.2×10^9 *A. salmonicida* cells were suspended in 4 ml of antibiotic-free Eagle's minimal essential medium containing 10% calf serum (MEM-10) and inoculated into the flask. The fathead minnow cells were observed for cytopathic effect after 36 hr of incubation at 11 C.

Results — When the five cultures from the storage file were plated on TSA, three of them yielded both rough and smooth colonies, one only rough, and one only smooth (Table 1). Colonies of three cultures, all of them smooth, were virulent to coho salmon at low concentrations. Though the culture of isolate III yielded only smooth colonies, these were not virulent at low concentrations.

No differences were observed between the R and S forms in the biochemical tests. Results generally agreed with Griffin et al. (1953).

The smooth colonies of No. 2 were rapid-growing, creamy, glistening, and had regular edges. In contrast the rough colonies were slightly slower-growing, dull brown, opaque, with slightly lobate edges. In 96 hr, the rough colonies developed a dark, raised center and transparent edges.

TABLE 1. Some characteristics of rough and smooth forms of *Aeromonas salmonicida* isolates.

Isolate	Size of colony (*mm*) grown 48 hr on TSA	Approx. number of bacteria/ml for LD50 to coho salmon
No. 2 (Leavenworth)		
R[a]	0.5	4×10^{12}
S	0.9	8×10^{4}
No. 34 (Snake River)		
R[a]	0.3	2×10^{12}
S	not found	–
No. 95 (Issaquah)		
R	1.1	7×10^{10}
S	1.1	2×10^{2}
No. 37 (Ontario)		
R	1.2	6×10^{11}
S	1.9	2×10^{2}
No. 111 (Winthrop)		
R	not found	–
S	0.6	4×10^{12}

[a]Rough form predominant at removal from storage; smooth form predominant in others.

When taken directly from the storage file, No. 34 displayed only rough colonies morphologically similar to the rough colonies of No. 2. Though No. 95 had only smooth colonies when taken from the file, after several transfers on TSA an R form was found, which was similar to No. 2 rough but was comparatively more virulent.

Both the rough and smooth colonies of No. 97 had slow growth rates. The smooth forms had a distinct glistening sheen, while the rough colonies were almost transparent.

No. III yielded smooth fast-growing colonies similar to the No. 2 smooth, but its virulence for coho was as low as that of the No. 2 rough.

The pathogenicities of the R and S forms of isolate 2 were contrasted (Table 2). Immediately after inoculation, all fish, including those controls inoculated with saline, showed darkened areas at the site of inoculation. Both test-fish groups developed open necrotic lesions. In the rough-inoculated fish, the lesions healed and almost all the fish were apparently healthy 2 weeks later. The few mortalities which occurred in these groups were thought to be due to secondary fungal invasion. In the smooth-inoculated fish, the lesion persisted and all the fish died within 96 hr of inoculation.

Differences in cytopathic effect were noted between the rough and smooth forms on tissue culture. The smooth forms destroyed the fathead minnow cells within 36 hr, while the rough forms had varying effects at this time. Early results were difficult

TABLE 2. Numbers of fish out of 10 (except as noted) from which *A. salmonicida* was recovered from surface lesions and kidneys at various intervals after inoculation with rough and smooth forms (1.2×10^9 bacteria) of isolate 2. No bacteria were recovered from the saline-inoculated controls.

Sample time after inoculation	Rough		Smooth	
	Lesion	Kidney	Lesion	Kidney
0 (pre-inoculation)	0	0	0	0
2	9	10	10	10
24	9	10	9	10
48	9	9	10	10
72	6	5	5[a]	5
96	1	1	–	–
120	0	1	–	–

[a]The remaining 5 fish were sampled at this time.

to calibrate, so further development of these techniques is planned.

Discussion — The occurrence of different colony morphologies arising from a single isolate has been well documented. The family Enterobacteriaceae, particularly *Salmonella* species, have been shown to develop the R and S forms (Weil and Saphra 1953). The smooth colonies generally have proved to be virulent (Archer and Rowley 1969). Pneumococcus strains develop a capsule coat in the virulent forms, and this coat deters macrophage destruction of the bacterium (MacLeod and Krauss 1950).

Our results on S and R forms in *A. salmonicida* agree with those of Duff (1937), except for that of the attenuated, smooth isolate of No. 111. These variants are now taken to be mutants, perhaps resulting from the environmental changes and nutritional conditions of artificial storage and media.

The difficulty of obtaining valid LD50s for coho salmon has been recognized in this and other laboratories (Spence and Amend personal communication). The problem is compounded when working with furunculosis, because not only do the conditions of the environment change, but the virulence of the bacteria could vary among the isolates and their corresponding forms. For these experiments, it was found necessary to calibrate virulence rates each time by running a parallel LD50 series with a standard virulent No. 95 smooth form. In this way any fluctuation in bacterial virulence, immunocompetence of the fish, or change in the environmental conditions could be partially recognized.

Klontz et al. (1966), in a study of the pathogenesis of furunculosis of rainbow trout, note the persistence of infection at the injection site of the virulent bacteria. In our work the fish inoculated with the S form displayed bacterial invasion, while most fish inoculated with the R form eliminated the bacteria (Table 2). All of the fish in the smooth-inoculated group died within 96 hr, while the rough-inoculated fish returned to an apparently healthy condition. However, a few fish still held the R forms in their kidneys by the end of the 96-hr sample. Bullock and Snieszko (1969) reported that *A. salmonicida* and other aquatic bacteria can exist internally under apparently normal hatchery field conditions. The mechanisms of this balance should be further explored. We know the fish are capable of recognizing certain antigens of furunculosis and of giving a specific humoral response (Anderson and Klontz 1970). The persistence of *A. salmonicida* may be due to factors present only in the smooth, virulent isolates.

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Preliminary Study of Sablefish Culture, a Potential New Industry

W. A. KENNEDY

Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

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A new industry may be possible based on capture of second-year juvenile sablefish (*Anoplopoma fimbria*) weighing about 300 g then rearing them to 4 kg for sale. I found sablefish easy to rear. Under growth-favouring conditions they gained about 150 g per fish per month, used about 5 kg wet weight of feed per kilogram gained, and had mortalities of less than 1% per month. Concentrations of at least 43 kg of fish/m^2 or 70 g/liter did not adversely affect growth or mortality.

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La capture de morues charbonnières, *Anoplopoma fimbria*, dans leur deuxième année, alors qu'elles pèsent environ 300 g, et leur élevage jusqu'à un poids de 4 kg peuvent être l'objet d'une industrie. Nous avons trouvé les morues charbonnières faciles d'élevage. Dans des conditions propices, elles croissent d'environ 150 g par sujet par mois, utilisant environ 5 kg (poids humide) de nourriture par kg de poids gagné et subissant une mortalité inférieure à 1% par mois. Des concentrations d'au moins 43 kg de poisson par mètre carré, ou 70 g par litre n'ont pas d'effet adverse sur la croissance ou la survie.

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SINCE late 1966 I have been rearing captive sablefish, *Anoplopoma fimbria* (Pallas), to assess its potential for fish farming. They are not cultured anywhere at present.

Some salient facts of life history pertinent to farming sablefish are as follows. Sablefish occur all around the rim of the North Pacific Ocean, including the Bering Sea, from Japan to California (Ueno 1965). Along the Canadian coast, typical adults are benthic near the outer edge of the continental shelf. They probably spawn about midwinter. The fertilized eggs are pelagic (Thompson 1941), and recently hatched young (Brock 1940) have been collected at the surface, some almost 300 km offshore. During their second year, as juveniles, they seem widespread in surface waters, being caught by casual angling both from ships more than 100 km offshore and from the docks of many British Columbia fishing villages (personal communication). Depths of occurrence increase with size (Kennedy and Pletcher MS 1968) until most adults are found at depths of 300–800 m (Heyamoto and Alton 1965; Kibezaki 1965). The Canadian fishery usually exploits the relatively small part of the adult population found at depths of less than 300 m.

Quantities of sablefish in their second year appear every summer along the British Columbia coast. For instance, salmon fishermen quit fishing near Port Hardy (northern Vancouver Island) in 1969 to avoid the unprofitable effort of clearing quantities of juvenile sablefish from their gear, and at Port Hardy in 1970 four men on a research vessel caught 75 in 20 min with handlines (baited hooks). Such juvenile sablefish have no commercial value, but are valuable when they weigh 4 kg or more, particularly after smoking when they are sold as "Alaska black cod," a gourmet item. Commercial sablefish culture would involve capturing some of the abundant juveniles and rearing them to 4 kg or more.

Materials and methods — Most (since 1969, all) sablefish used for rearing experiments were, when captured, typical of the juveniles that appear along the B.C. coast each summer. They averaged about 300 g each and over 90% were about 1.5 years old, the rest a year older. Before 1969 they were caught by trawling, but since then baited hooks have been used.

Some lots of sablefish were reared for extended periods in round Fiberglas tanks, 245 cm diameter and 90 cm high. Others were held in oval Fiberglas tanks, 140 cm long, 80 cm wide, and 90 cm high. Sea water from Departure Bay was pumped directly into both types of tank at about 20 liters/min, aerated, and maintained at a depth of about 60 cm.

Various feeds were stored at –25 C or colder, being cut into "bite-size" chunks (10–100-cm^3 pieces), where appropriate, while still frozen. Usually fish were fed daily. Lots with prescribed diets including more than

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one kind of feed were fed one kind exclusively for several days, then rotated to another. An overabundance of feed was supplied, the amount offered being recorded whether it was eaten or not.

The proportion by weight of feeds used by the six lots of fish reported in Table 1 were:

Lot 1 — Herring, whole, 100%
Lot 2 — Dogfish, eviscerated, head-off, 100%
Lot 3 — Herring, whole, 58%
Dogfish, eviscerated, head off, 42%
Lot 4 — Herring whole, 62%
Chicken offal with additives[1], 29%
Mussel meats, 3%
Moistened shrimp offal meal, 3%
Moistened, reworked Oregon pellet, 3%
Lot 5 — Dogfish, whole, 100%
Lot 6 — Herring, whole, 45%
Dogfish, whole, 55%

Fish used in crowding experiments were fed roughly 50% whole herring and 50% whole dogfish.

Usually fish were weighed every month while anaesthetized with M.S. 222, and after draining for 5 sec.

Results — General suitability for culturing. About 20% of fish reared became blind in at least one eye from obscure causes, although injury from the tank and its appurtenances was one factor. There were no other pathological problems apart from tag-inruced infection. They withstood abuse unusually well and survived several times the dosage of M.S. 222 that is lethal to salmonids. Crude experiments indicated that they tolerate dissolved oxygen concentrations as low as 1 ppm at 12 C.

Growth, mortality, and feeding efficiency. Six lots of fish were reared in circular tanks for extended periods; each lot consisted of fish captured at the same time and place, being initially juveniles of roughly the same size. Lots 1 and 3 were continued until the largest members were commercial size (4 kg). Lot 2 was terminated when tag-induced infection adversely affected growth and mortality (Kennedy 1970), and lots 4, 5, and 6 were continued beyond time of writing.

Figure 1 indicates growth patterns for each lot. Disregarding for the moment the June–September and the January–May sections of the lines for lots 4, 5, and 6 which are discussed below, Fig. 1 indicates that, over the weight range used, these well-fed captive sablefish gained weight at a constant rate rather than at a rate dependent on size. In most cases the constant rate of gain was roughly 150 g/fish per month but in lot 1 it was about 120 g/fish per month, possibly because of our inexperience and an exclusively herring diet, while in lot 4 after September it was also less, possibly because of changing to a diet based on chicken offal.

A noticeable feature of Fig. 1 is the reduced (sometimes negative) rate of growth of lots 4, 5, and 6 during the warm-weather period starting about 8 months after initiation. Kennedy and Smith (MS 1971) noted that groups of sablefish averaging more than 1.8 kg by May are adversely affected by the relatively high summer temperatures of the sea water available at Nanaimo for fish culture, although those averaging less than 1.8 kg are not adversely affected. Adverse effects include reduced growth rates, so the poor summer growth in lots 4, 5, and 6 is no surprise. Fish in lots 2 and 3 were presumably too small to be affected during their respective summers in captivity. But although the average weight of lot 1 became 1.8 kg in June, its growth rate continued unchanged. Presumably, this difference in response was associated with a more adverse summer temperature regime experienced by lots 4, 5, and 6 in 1970 than by lot 1 in 1967. That 1970 was the more severe is indicated by the number of days respectively during which specified seawater temperatures were exceeded as follows:

Temp (*C*):	12	13	14	15	16
1967	89	49	30	17	10
1970	110	72	50	35	21

[1]No chicken offal until August 1970; chicken offal exclusively after September 1970.

TABLE 1. Rearing data from the six lots of sablefish reared in 245-cm diam tanks. See text for details on diets.

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Diet	Herring	Dogfish	Herring + Dogfish	Various	Dogfish	Herring + Dogfish
Start	Dec. 1966	Mar. 1968	Jan. 1969	Aug. 1969	Sept. 1969	Sept. 1969
Finish	Mar. 1968	Nov. 1968	May 1970	May 1971	May 1971	May 1971
No. of fish initially	31	32	30	35	35	35
No. of fish finally	29	32	25	25	20	18
Mortality rate, %/month	0.4	0.0	1.0	1.4	2.1	2.4
Kg of feed used/kg gained	9.6	5.0	5.0	7.3	5.1	5.7

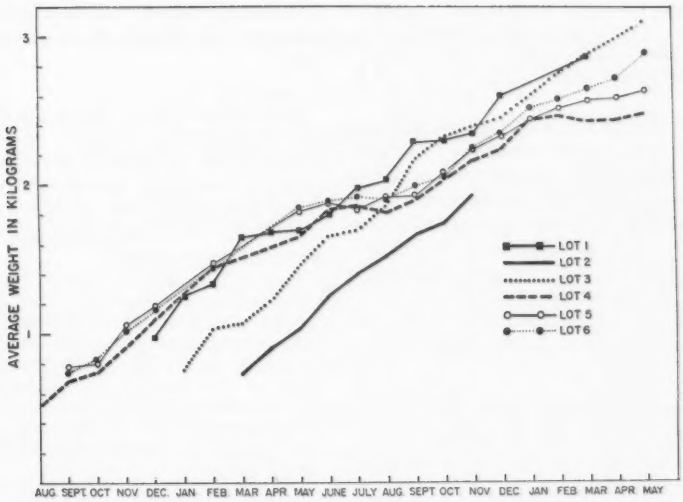

FIG. 1. Growth patterns of 6 lots of sablefish reared in captivity. Rearing data are given in Table 1.

In nature, sablefish of more than 1.8 kg are unlikely to be in water that exceeds 10 C.

Average size was slightly smaller in lot 1 than in lots 4, 5, and 6 at the beginning of the warmwater period which might have also influenced response.

Lots 4, 5, and 6 also grew slower than usual between their second January and May. Several times during the period these lots, as well as other tanks of sablefish, abruptly and simultaneously lost appetite and only slowly regained it. There is good reason to suspect that poor-quality sea water was supplied occasionally during pump changeovers.

Additional information on lots 1–6 is given in Table 1. As Kennedy and Smith (MS 1971) report, the adverse effects of summer temperatures on larger sablefish include relatively high mortality. Higher mortalities in lots 4–6 than in lots 1–3 were therefore expected. In lots 4–6, 19 of the 42 fish that died, almost half, died during the four warmwater months. Exclusive of these atypical months, mortalities in lots 4–6 averaged just over 1% per month.

Even when a fish is not growing it requires considerable feed, so the ratio of amount fed to amount gained is higher when growth is slower. Values of the ratio given in Table 1 are therefore higher for lots 4–6 than they would have been had there been no period of slow growth. If the June–September period of slow growth is disregarded, the values would be 6.3, 4.4, and 4.9, respectively, instead of 7.3, 5.1, and 5.7 as in Table 1. The revised values are reasonably close to values for lots 2 and 3 but notably different from the value for lot 1. The unusually high feed requirement for a unit of gain in lot 1 may have resulted from our inexperience during this first attempt to rear sablefish, or from an exclusive diet of frozen herring.

For purposes of evaluating factors pertinent to commercial operations, it seems legitimate to exclude data for times when water temperature was unfavorably high, since easily made changes would provide water of a suitable temperature. When conditions for growth were favorable, sablefish gained about 150 g/fish per month, had a mortality rate of less than 1% per month, and gained about 1 kg for every 5 kg of feed (wet weight) used. About 10% of the feed used was not eaten, so the 5:1 ratio represents a conversion rate (wet weight to wet weight) of roughly 4.5:1.

Crowding rate. Four oval tanks were used to study the effects of crowding on growth and mortality. Conditions in all four tanks were the same except that the biomass differed from tank to tank. Weights of approximately 10, 20, 30, and 40 kg of sablefish/tank, respectively, were maintained by removing enough individual fish at random once a month to compensate for increases in biomass by growth. In each tank initial average weights of individual fish were close to 750 g.

The experiment began September 15, 1970, and continued until May 14, 1971. Results were as follows:

Tank number:	1	2	3	4
kg fish/tank:	40	30	20	10
g gained/fish/month:	150	120	180	130
Monthly mortality (%):	0.6	1.6	1.2	0.0

Growth rate (average 140 g/fish per month) was much the same regardless of crowding. Mortality rate (average 0.8%/month) was more variable but showed no tendency to increase or decrease as rate of crowding increased. To put mortality rates in perspective, note that just one death in tank 4 instead of in tank 2 would have made the tank 4 mortality rate the highest instead of the lowest.

There has to be a limit to the number of fish that can be kept in a given space without adversely affecting growth or mortality rate. The amount of fish even in the most crowded of the four experimental tanks was obviously below that limit. Results from two earlier experiments — suspect because in one case the diet was herring exclusively and in the other there was heavy mortality attributed to tag-induced infection — were consistent with those of this experiment.

The bottom area of each tank was 0.93 m^2 and each normally held about 570 liters of water. Therefore, if (as seems probable) the factor that limits the rearing density of sablefish in a given tank is the area of tank bottom, then at least 43 kg of sablefish/m^2 can be accommodated without adverse effects. If the limiting factor is water volume, then the value is at least 70 g of sablefish/liter.

Cultured sablefish as a product. When the three largest sablefish in lot 1 reached commercial size (4 kg) in March 1968, they were slaughtered and smoked commercially. They were formally tasted, along with trawl-caught smoked sablefish, by an experienced taste panel at the Fisheries Research Board of Canada Vancouver Laboratory. The panel reported favorably on the cultured sablefish. Some panel members noted that cultured sablefish tasted different from, but not inferior to, trawl-caught sablefish. The difference probably arose because the cultured sablefish had been frozen immediately after killing and were fresher when smoked.

In subsequent informal taste tests, tasters reported favorably on the flavor of smoked cultured sablefish.

Discussion — These results are far from adequate cor assessing the feasibility of culturing sablefish fommercially. However it is true that more than 4 years of culturing sablefish experimentally have failed to indicate any circumstances that would make it obviously infeasible. Sablefish culture *is* a potential new industry.

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Detection of Antibodies to *Aeromonas liquefaciens* in Fish by an Indirect Fluorescent Antibody Technique

D. H. LEWIS AND N. L. SAVAGE

Department of Veterinary Microbiology
Texas A&M University, College Station, Texas 77843, USA

LEWIS, D. H., AND N. L. SAVAGE. 1972. Detection of antibodies to *Aeromonas liquefaciens* in fish by an indirect fluorescent antibody technique. J. Fish. Res. Bd. Canada 29: 211–212.

A technique for detecting antibodies in fish is described that may be of value in screening fish populations for various disease agents. The technique is based on the reaction between fluorescein-labelled antifish globulin and a fish antibody–antigen complex. The immune responses of *Pimephales promelas*, *Notemigonus crysoleucas*, and *Fundulus grandis* to *Aeromonas liquefaciens* were demonstrated by the technique.

LEWIS, D. H., AND N. L. SAVAGE. 1972. Detection of antibodies to *Aeromonas liquefaciens* in fish by an indirect fluorescent antibody technique. J. Fish. Res. Bd. Canada 29: 211–212.

Les auteurs décrivent une méthode de détection d'anticorps chez les poissons par laquelle des populations peuvent être séparées en fonction de divers agents pathogènes. Cette méthode est basée sur la réaction de la globuline antipoisson marquée à la fluorescéine avec un complexe anticorps–antigène de poisson. A l'aide de cette technique, les auteurs démontrent les réactions immunisantes de *Pimephales promelas*, *Notemigonus crysoleucas*, et *Fundulus grandis* contre *Aeromonas liquefaciens*.

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THE delay associated with bacteriologic processing of large numbers of fish to determine whether disease agents are present led us to study a serologic approach as a possible alternative to conventional cultural procedures. An indirect fluorescent antibody (IFA) technique was considered appropriate, since it would allow rapid testing of small quantities of individual serum samples from several species of fish.

The development of antibodies in fathead minnows (*Pimephales promelas*), golden shiners (*Notemigonus crysoleucas*), and gulf killifish (*Fundulus grandis*) to heat-killed *Aeromonas liquefaciens* cells was monitored by the IFA technique as described below.

The fish were obtained from local sources and maintained in 75-liter aquaria at ambient temperature (20–22C) for 1 month prior to use. Conventional bacteriological methods described by Bullock (1961) were utilized to monitor the fish. The killifish were maintained in artificial sea water (15‰) and the fathead minnows and golden shiners in aged tap water. The water from each aquarium was circulated through filters containing 5-kg charcoal-oyster shell (1:2 mixture)/75 liters water at a rate of 3 liters/min. The filters were changed each month.

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Procedure — Antifish serum was developed in rabbits using plasma from approximately 100 specimens of each species of fish. The caudal fins were severed and the blood was collected in heparinized capillary tubes (100 mm long and 1.2 mm ID). The tubes were sealed on one end and centrifuged in a clinical hematocrit centrifuge. The tubes were then broken at the erythrocyte-plasma interface and the plasma portions pooled. Antisera to fish plasma were prepared by injecting rabbits with alum precipitates of plasma according to the method of Proom (1943). Ten to 14 days after the last injection, the rabbits were bled and the sera conjugated with fluorescein isothiocyanate as described by Goldman (1968).

The antigen was prepared by harvesting the confluent growth of *A. liquefaciens* from four brain-heart-infusion agar plates into 100 ml saline. This suspension was autoclaved (15 lb, 15 min at 121 C), washed twice in physiologic saline, and adjusted to a $BaSO_4$ standard suspension equal to 10^9 organisms/ml. The fish received approximately 0.05 ml of the suspension intraperitoneally.

Plasma samples used in the IFA test were obtained from five fish of each species at weekly intervals, as described above. Twofold serial dilutions of plasma in phosphate-buffered saline at *p*H 7.2 (PBS) were used for determining antibody titer. Preinoculation samples were derived 1 week prior to inoculating the fish.

The IFA test was performed by adding the plasma samples to smears of *A. liquefaciens*. The preparations were incubated 45 min at ambient temperature and

TABLE 1. Immune responses of fish inoculated with killed *Aeromonas liquefaciens* cells. Values listed express titers as measured by an indirect fluorescent antibody technique.

Fish	Week from inoculation								
	−1	1	2	3	4	5	6	7	8
Fathead minnow	8	32	128	64	512	128	128	128	128
Golden shiner	32	32	128	254	512	254	254	254	254
Gulf killifish	32	128	128	1028	1028	512	512	512	512

washed with PBS, and the appropriate antifish serum conjugate added. After 45 min incubation at 37 C, the preparations were soaked three times in PBS (15 min each) and mounted.

The specificity of the antigen–antibody reactions was tested by: (1) incubating the smears with unlabelled rabbit anti-*A. liquefaciens* serum prior to adding fish plasma, (2) testing the capacity of fish plasma to inhibit fluorescence with specific anti-*A. liquefaciens* conjugate, and (3) by incubating smears with only the antifish conjugate. Observations were made with a Leitz Labolux-D fluorescence microscope using the standard HBO 200 mercury vapor lamp as light source, BG-12 excitation, K430 barrier filters, and a Letiz cardiod darkfield condenser. Fluorescence was not seen in the specificity tests.

Discussion — The immune responses of the fish utilized in this study were characterized by the development of maximum antibody titers to *A. liquefaciens* 4–5 weeks after antigenic stimulation and by the maintenance of high titered antibodies for at least 8 weeks (Table 1). Although bacteriologic examination of the experimental fish failed to reveal *A. liquefaciens* in them, the presence of low titered antibodies in the preinoculation plasma samples suggested that the fish had been exposed to *A. liquefaciens* prior to experimental exposure. Subsequent bacteriologic examination of the suppliers stock of golden shiners revealed the presence of *A. liquefaciens* in 2% of the fish examined. Stocks of fathead minnows and gulf killifish were not available for bacteriologic examination.

The observation that antibodies to *A. liquefaciens* in fish could be detected by the IFA technique suggests the potential value of the technique in screening fish populations for *A. liquefaciens*. Antibodies to various other disease agents could be detected if appropriate antifish globulin were available and if the specificity of the IFA reaction were demonstrable. However, the possibility that nonpathogenic aquatic bacteria are capable of inducing false positive serologic responses in the fish must be considered when applying the IFA technique to screening procedures. In a study on distinguishing *Aeromonas* sp. serologically from similar organisms, Liu (1961) was unable to demonstrate cross- reactions between *Aeromonas* sp., *Serratia* sp. and species of other genera of the families Enterobacteriaceae and Pseudomonodaceae when cell free filtrates were used as antigens. In another study by Lewis and Allison (1971), direct fluorescent antibody methods failed to reveal cross reactions between *A. liquefaciens*, various members of Enterobacteriaceae and *Achromobacter* sp. Nonetheless, the practical utility of the IFA screening procedure can only be established by field studies and further research.

Although cultural methods are of considerable diagnostic value, supplemental methods of ascertaining the disease status of fish should also be considered. Those based upon detecting antibodies to specific disease agents appear to facilitate and broaden the monitoring process. The IFA procedure offers advantages over certain other serologic procedures in that it usually requires a minimal amount of test serum, is highly specific and is applicable to a variety of antigen-antibody combinations. The significance of being able to detect antibodies to disease agents lies in the potential value of ascertaining exposure of the host to those agents regardless of whether or not the agents can be recovered.

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Occurrence of *Eukrohnia bathypelagica* Alvariño 1962 (Chaetognatha) in the Atlantic Waters of Canada

ARMANDO J. G. FIGUEIRA

Canadian Oceanographic Identification Centre
National Museum of Natural Sciences, Ottawa, Ont.

FIGUEIRA, A. J. G. 1972. Occurrence of *Eukrohnia bathypelagica* Alvariño 1962 (Chaetognatha) in the Atlantic waters of Canada. J. Fish. Res. Bd. Canada 29: 213–214.

The chaetognath *Eukrohnia bathypelagica* Alvariño 1962 is recorded for the first time in the waters of eastern Canada. Some remarks on the morphology of the only specimen obtained are included. It is suggested that this species may not be rare in the region.

FIGUEIRA, A. J. G. 1972. Occurrence of *Eukrohnia bathypelagica* Alvariño 1962 (Chaetognatha) in the Atlantic waters of Canada. J. Fish. Res. Bd. Canada 29: 213–214.

L'auteur mentionne pour la première fois la présence du chétognathe *Eukrohnia bathypelagica* Alvariño 1962 dans les eaux de la côte est du Canada. Il fait aussi quelques remarques sur la morphologie du seul spécimen capturé et suggère que l'espèce n'est peut-être pas rare dans la région.

Received August 18, 1971

Eukrohnia bathypelagica is a cosmopolitan, mesobathyplanktonic chaetognath that has never been recorded in the Atlantic Ocean north of the equator except for a small area in the Gulf of Guinea (Ducret 1965; Alvariño 1969) although it seems to be fairly abundant in the south Atlantic (Alvariño 1969).

During the identification of zooplankton from a vertical haul made at the entrance of the Gulf of St. Lawrence on *Baffin* cruise 1768, a specimen of *E. bathypelagica* was found. The sample was collected on May 8, 1968, between 2217–2228 hr with a net of 75 cm mouth diam at 47°15.5′ N and 59°59′ W. Depth of the haul was 440 m and the depth to bottom 447 m. This specimen is deposited in the collection of the National Museum of Natural Sciences, Ottawa, Canada, catalogue no. 611.

Total length of the specimen (tail fin excluded) is 28.2 mm and the tail measures 8.6 mm, about one-third of the total length. Other anatomical characteristics such as general shape of the head and eyes, shape of the coiled ovaries, shape and position of the seminal vesicles, shape of the lateral fins, and the tip of the hooks are similar to those typical of *E. bathypelagica*.

The head is somewhat damaged, and an accurate count of teeth is difficult but there seem to be slightly more than 22, the greatest number previously recorded for *E. bathypelagica*. The slightly greater number of teeth in this specimen may be due to its size (larger than any previously recorded specimen), age, or to environmental conditions, as has been reported for other chaetognaths (Kado 1954; Murakami 1959; Alvariño 1962; Ducret 1965; Furnestin 1965; Ghirardelli 1968). Remains of the brood sacs are very distinct, and the ovaries are apparently regenerating. This indicates that, in the collection area, the species may undertake a second cycle of maturity.

The present record of *E. bathypelagica* strengthens the suggestion by Alvariño (1962) that part of the specimens referred to *E. hamata* by Kramp (1939) may belong to *E. bathypelagica*.

According to Ducret (1965, 1968), *E. bathypelagica* is not rare in West African waters. Careful identification of future specimens may also show a similar situation in the waters of eastern Canada.

Acknowledgments — Thanks are due to Dr R. J. Conover, Fisheries Research Board of Canada Marine Ecology Laboratory, Bedford Institute, Dartmouth, N.S., for his permission to report on the present specimen.

ALVARIÑO, A. 1962. Two new Pacific chaetognaths. Their distribution and relationship to allied species. Bull. Scripps Inst. Oceanogr. Univ. Calif. 8: 1–50.

1969. Los quetognatos del Atlantico. Distribución y notas essenciales de Sistemática. Trab. Inst. Espan. Oceanogr. 37: 1–290.

DUCRET, F. 1965. Les espèces du genre *Eukrohnia* dans les eaux équatoriales et tropicales africaines. Cah. O.R.S.T.O.M. (Off. Rech. Sci. Tech. Outre-Mer) Ser. Océanogr. 5(2): 63–78.

1968. Chaetognathes des campagnes de l'"Ombango" dans les eaux équatoriales et tropicales afri-

Printed in Canada (J2279)

caines. Cah. O.R.S.T.O.M. (Off. Rech. Sci. Tech. Outre-Mer) Ser. Océanogr. 6(1): 95–141.

FURNESTIN, M.-L. 1965. Variations morphologiques des crochets au cours du développement dans le genre *Eukrohnia*. Rev. Trav. Inst. Sci. Techn. Pêches Mar. 29(3): 275–284.

GHIRARDELLI, E. 1968. Some aspects of the biology of the chaetognaths. Advan. Mar. Biol. 6: 271–375.

KADO, Y. 1954. Notes on the seasonal variation of *Sagitta crassa*. Annot. Zool. Jap. 27(1): 52–55.

KRAMP, P. L. 1939. The Godthaab expedition 1928. Chaetognatha. Medd. Grønland. 80(5): 1–40.

MURAKAMI, A. 1959. Marine biological studies on the planktonic Chaetognatha in the Seto inland sea. Part I. Studies on the occurrence and habits of chaetognaths. Bull. Naikai Reg. Fish. Res. Lab. 12: 1–186.

Recent Articles on FRB Investigations Published in Other Periodicals

Until 1970, reprints of these articles had been included in an annual volume of "Studies," composed of two parts. The final binding was the 1969 Studies, Part 2, which included No. 1355. These are no longer bound and distributed. We continue, however, to number and list all articles, which henceforth may be obtained in reprint form only from the author or originating FRB establishment. The number following each title refers to the FRB establishment listed below.

(1) Fisheries Research Board of Canada
Biological Station
P.O. Drawer 100
Nanaimo, British Columbia

(2) Fisheries Research Board of Canada
Vancouver Laboratory
6640 N.W. Marine Drive
Vancouver 8, British Columbia

(3) Fisheries Research Board of Canada
Pacific Environment Institute
4160 Marine Drive
West Vancouver, British Columbia

(4) Fisheries Research Board of Canada
Freshwater Institute
501 University Crescent
Winnipeg 19, Manitoba

(5) Fisheries Research Board of Canada
Arctic Biological Station
P.O. Box 400
Ste. Anne de Bellevue, Quebec

(6) Fisheries Research Board of Canada
Biological Station
St. Andrews, New Brunswick

(7) Fisheries Research Board of Canada
Marine Ecology Laboratory
Bedford Institute
P.O. Box 1006
Dartmouth, Nova Scotia

(8) Fisheries Research Board of Canada
Halifax Laboratory
P.O. Box 429
Halifax, Nova Scotia

(9) Fisheries Research Board of Canada
Biological Station
St. John's, Newfoundland

1600. ZITKO, V., O. HUTZINGER, AND S. SAFE. 1971. Retention times and electron-capture detector responses of some individual chlorobiphenyls. Bull. Environ. Contam. Toxicol. 6: 160–163. (6)

1601. BROCKERHOFF, H. 1971. On the function of bile salts and proteins as cofactors of lipase. J. Biol. Chem. 246: 5828–5831. (8)

1602. SHIEH, H. S. 1971. The incorporation of radioactive compounds into glycerides of the American lobster, *Homarus americanus*. Int. J. Biochem. 2: 423–426. (8)

1603. HUTZINGER, O., S. SAFE, AND V. ZITKO. 1971. Polychlorinated biphenyls: synthesis of some individual chlorobiphenyls. Bull. Environ. Contam. Toxicol. 6: 209–219. (6)

1604. ZITKO, V. 1971. Polychlorinated biphenyls and organochlorine pesticides in some freshwater and marine fishes. Bull. Environ. Contam. Toxicol. 6: 464–470. (6)

1605. MUNDIE, J. H. 1971. The diel drift of chironomidae in an artificial stream and its relation to the diet of coho salmon fry, *Oncorhynchus kisutch* (Walbaum). Can. Entomol. 103: 289–297. (1)

1606. TAYLOR, F. H. C. 1971. Variation in hatching Pacific herring (*Clupea pallasii*) eggs with water depth, temperature, salinity and egg mass thickness. Rapp. Proces-Verbaux Reunions Cons. Perma. Int. Explor. Mer 160: 34–41. (1)

Additional FRB Publications

The Fisheries Research Board of Canada also publishes a series of *Bulletins*, each on a specific topic. These are for sale by Information Canada, Ottawa, and remittances must be in advance, payable in Canadian funds to the order of the Receiver General of Canada. *Bulletins* are also available from local booksellers and Information Canada bookshops throughout Canada.

The *Annual Report* of the Board and the biennial *Review* of investigations are available free, on request. All publications may be referred to at Board establishments located at: Ottawa; Nanaimo and Vancouver, B.C.; Winnipeg, Man.; Ste. Anne de Bellevue, Que.; St. Andrews, N.B.; Halifax and Dartmouth, N.S.; and St. John's, Nfld.

L'Office des recherches sur les pêcheries du Canada publie également une série de *Bulletins*, chacun traitant sur un sujet spécifique. Les publications de l'ORP sont vendues par Information Canada à Ottawa. Les remises, payables d'avance en monnaie canadienne, doivent être établies à l'ordre du Receveur général du Canada. Les *Bulletins* sont aussi en vente chez votre libraire et dans les librairies d'Information Canada.

Vous pouvez obtenir le Rapport Annuel et la Revue biennale gratuitement. On peut consulter ces ouvrages aux établissements de l'Office situés à Ottawa (Ont.), à Nanaïmo et à Vancouver (C.-B.), à Winnipeg (Man.), à Ste-Anne-de-Bellevue (P.Q.), à St-Andrews (N.-B.), à Halifax et à Dartmouth (N.-E.), et à St-Jean (T.-N.).

Journal Fisheries Research Board Canada

Guide to Authors

Details on typing and other items in preparing copy are given in a guide for typists. Also, a list of recommended spellings of about 100 words common in fisheries journals is available from the Office of the Editor.

Editorial Practices

Abstracts should be provided in both English and French.

The *Style Manual for Biological Journals* (2nd ed. American Institute of Biological Sciences, 2000 P St. NW., Washington, D.C.) is, with few exceptions, used as the authority in matters of form. *Webster's Third New International Dictionary* is the standard for spelling and division of words in English; *le Grand Larousse Encyclopédique*, for those in French. Exceptions are made for manuscripts that follow the *Oxford English Dictionary* entirely. Titles of periodicals are abbreviated as in the *Biological Abstracts* list. References to literature are made by the name-and-year system. Manuscript reports are included in the list of references, but are identified both there and in the text by the letters "MS" before the year. The *Journal* follows the spelling recommended in *A List of Common and Scientific Names of Fishes from the United States and Canada* (Third Edition, 1970), Special Publication No. 6 of the American Fisheries Society.

Notes are distinguished from *papers* on the basis of scope or completeness, rather than quality, of the research. They may be on problems with narrow, readily defined limits; on fishing gear or methods, or research techniques; on advances in knowledge arising as by-products of broader studies; on progress in projects that were discontinued before completion; or on preliminary findings that warrant publication before problems are resolved satisfactorily. Or they may be used to establish priority in publication. They may be organized with as much flexibility as papers except that they may have no centered headings. They should take no more than four pages in the *Journal*.

In general, *series titles* should be avoided.

Illustrations

Line drawings are preferably made with black india ink on white drawing or tracing paper or on coordinate paper with blue grids. All lines, symbols, letters, and numerals must be neat, and legible when the illustration is reduced to the appropriate size. Drawings should be grouped, when feasible, for economy of space. Originals must be submitted and should be less than 20 inches in the greater dimension for full-page illustrations, and proportionately smaller for those taking less than a page. Drawings must not be rolled for mailing.

Prints of photographs should be made on glossy paper with a wide range in tone. They should be cropped, squared, and mounted with rubber cement on white cardboard, with no space between those arranged in groups.

Proofs and Reprints

Galley proof is sent to the author, and he is responsible for detecting errors in printing as well as in content.

Fifty reprints, without covers, are supplied free. Additional copies needed must be ordered, on the form provided, when the galley proof is returned.

Checklist on Manuscripts

Attention to the following questions will expedite appraisal of manuscripts by referees and editors. The same questions are recommended to referees who review manuscripts for the *Journal*.

General

Is there new knowledge in the report worth publishing?

Are the findings, interpretations, and conclusions sound, and relevant to the purpose of the study?

If the manuscript is merely confirmatory, is it worth publishing?

Does the manuscript need to be rewritten before the work can be assessed?

Is the contribution placed in the proper perspective concerning the state of knowledge of the subject?

Is the manuscript too long?

Are all the tables and figures needed, and organized for economy of space?

Would any of the text be clearer if condensed?

Should some of the data be made available separately, in a manuscript report or at a data repository?

Should the manuscript be condensed as a Note?

Does the organization of the manuscript follow logically from the statement of purpose in the introduction?

Are summary statements given at the beginnings of sections and paragraphs, and are details in sections and paragraphs relevant to their topics?

Are there inconsistencies between tables or figures and the text, or within the text?

If the manuscript is from a thesis, does it retain characteristics common in these but not desirable in journals?

Parts of the Manuscript

Does the *title* encompass the content of the report?

Does the *abstract* give the essentials of the new knowledge?

Has the *introduction* all the important guideposts for orienting the reader?

Is review of the literature limited to defining the problem?

Are details of *materials and methods* limited to what scientists need in understanding the design of the study and in judging adequacy of the data obtained?

Are generalizations on the *results* adequate?

Are findings distinguished from inferences from them?

Is *discussion* limited to interpretation and significance of the findings?

If there are loopholes in interpretation, are they acknowledged? Should they be overcome?

Should other interpretations be recognized?

Journal of the Fisheries Research Board of Canada

Guide des auteurs

Des détails sur le tapage et certains autres item sont donnés dans le "Guide pour les secrétaires d'auteurs." Aussi, une liste d'épellations recommandées d'environ 100 mots relatifs aux articles sur les pêcheries est disponible au bureau du Directeur de la publication.

Disposition générale

Les résumés doivent être fournis en anglais et en français.

Le *Style Manual for Biological Journals* (deuxième édition, publié par l'American Institute of Biological Sciences, 2000, rue *P* N.-O., Washington, D.C.), a été adopté comme guide des auteurs. Le *Third New International Dictionary* de Webster, dans le cas de l'anglais, et le *Grand Larousse Encyclopédique*, dans le cas du français, font respectivement autorité pour l'orthographe et la séparation des mots. Une exception est faite à l'égard des travaux en anglais qui se conforment entièrement à l'*Oxford English Dictionary*. Les titres de périodiques sont abrégés selon la *Biological Abstracts*. Toute référence à la littérature doit suivre le système nom-année. Les rapports manuscrits sont inclus dans la liste des références, les lettres "MS" avant l'année les identifient dans les références et dans le texte. Le *Journal* se sert des épellations recommandées dans *A List of Common and Scientific Names of Fishes from the United States and Canada* (Troisième édition, 1970), Publication spéciale No 6 de l'American Fisheries Society.

Les *notes* se distinguent des écrits d'après l'étendue de la recherche plutôt que par la qualité de la recherche. Les notes peuvent être sur des travaux de recherche de portée restreinte, susceptibles de découler d'investigations plus considérables, pour la description de techniques de recherche et de méthodes de pêche, pour l'établissement de priorités de publication, et pour faire connaître les renseignements utiles tirés d'entreprises qui ont été interrompues avant d'avoir été achevées. Si la portée de la Note le permet, elle peut être disposée comme un mémoire. D'autre part, la disposition est flexible. La longueur ne doit pas dépasser quatre pages imprimées.

En général, les mémoires en série doivent être évités.

Les illustrations

Les dessins au trait doivent être exécutés à l'encre de chine sur papier à dessin blanc ou sur papier à calquer, ou sur papier à coordonnées avec quadrillage bleu. Les lignes, les symboles, les lettres et les chiffres doivent tous être propres. Ils doivent être lisibles quand ils sont réduits à la grandeur voulue pour la reproduction désirée. Les dessins doivent être groupés, si la chose est possible, de façon à utiliser tout l'espace disponible. Les originaux doivent être soumis et devraient mesurer moins de 20 pouces dans le sens le plus long pour les illustrations de pages entières, et proportionnellement plus petit pour les illustrations de moins d'une page. Les dessins doivent être postés à plat.

Les épreuves des photographies doivent être tirées sur papier glacé et accuser une gamme étendue de teintes. Elles doivent être coupées, dressées et montées, au moyen de dissolution, sur carton blanc, sans laisser d'espace entre celles qui sont disposées par groupes.

Epreuves et tires a part

Les épreuves en placards sont adressées à l'auteur et la responsabilité de toute erreur qui peut y rester lui incombe.

Cinquante tirés à part, sans couverture, sont fournis gratuitement. L'auteur peut profiter du renvoi des épreuves en placards pour commander d'autres tirés à part.

Liste de contrôles pour manuscrits

Une attention particulière portée sur les questions suivantes facilitera l'évaluation des manuscrits par les arbitres et les rédacteurs. Les mêmes questions sont recommandées aux arbitres qui font la critique des livres pour le *Journal*.

Generalites

Est-ce que les connaissances nouvelles du rapport méritent d'être publiées?

Les découvertes, les interprétations et les conclusions sont-elles solides et pertinentes au but de l'étude?

Si le manuscrit est tout simplement corroboratif, mérite-t-il d'être publié?

Le manuscrit doit-il être récrit avant d'évaluer le travail?

La contribution est-elle placée dans une perspective appropriée relative à l'état des connaissances du sujet?

Le manuscrit est-il trop long?

Les tables et figures sont-elles toutes nécessaires et arrangées pour économiser le plus d'espace?

Le texte serait-il plus clair s'il était condensé?

Est-ce qu'une partie des données devrait être disponible séparément, soit dans un rapport ou dans un dépôt des données?

Le manuscrit devrait-il être condensé en une note?

Est-ce que la préparation du manuscrit suit la logique mentionnée dans l'introduction?

Y a-t-il des exposés sommaires au début de chaque section et paragraphe, et les détails de ces sections et paragraphes sont-ils pertinents aux sujets?

Y a-t-il des contradictions entre les tableaux et les figures du texte, ou dans le texte même?

Si le manuscrit est tiré d'une thèse, contient-il des caractéristiques communes à cette dernière, mais indésirables dans un journal?

PARTIES DU MANUSCRIT

Le titre renferme-t-il le contenu du rapport?

Le résumé donne-t-il l'essentiel des connaissances nouvelles?

L'introduction a-t-elle tous les points importants afin d'orienter le lecteur?

Le renvoi bibliographique se limite-t-il à la définition du problème?

Les détails du matériel et des méthodes employées sont-ils limités à un minimum pour que les scientifiques comprennent le but de l'étude et puissent porter un jugement adéquat sur les données obtenues.

Les généralisations sur les résultats sont-elles adéquates?

Les conclusions sont-elles déduites des résultats?

La discussion est-elle limitée à l'interprétation et la signification de ces découvertes?

S'il y a des échappatoires dans l'interprétation, sont-elles reconnues? Devraient-elles être maîtrisées?

Devrait-on accepter d'autres interprétations?

Journal
Fisheries
Research
Board
Canada

Guide for Typists Preparing Copy

Read the "Guide to Authors" in the current volume of the *Journal*. When in doubt about how to type or arrange details, follow *Journal* practice.

Type the manuscript on white bond paper, not flimsy, preferably size 8.5 × 11 inches (21.5 × 28 cm). If possible, use paper with the lines numbered in the margin. Leave all margins at least 1 inch (2.5 cm) wide. Use a nylon or carbon ribbon and keep the typewriter keys clean.

Double-space all parts of the manuscript, including tables, captions for illustrations, footnotes, and the reference list. Underline only material that is to be printed in italics. Indent the first line of each paragraph in the text and of each footnote.

In titles and headings, capitalize only the first word and proper names and adjectives. For small capitals, use small letters.

Indicate all text footnotes by superscript arabic numbers. Number them consecutively throughout the manuscript, starting with those on the title page. Place each footnote immediately below the reference to it, separating it from the text by horizontal lines.

On the first page type only the title, the authors' names and affiliations, related footnotes, and the running head (Appendix A). Type the abstract on a separate page (Appendix B). Number all pages, beginning with the title page and including those for tables and captions for illustrations.

Have the author check the finished manuscript, and send two copies (the ribbon copy and a carbon copy or a photocopy) to the Office of the Editor.

Tables

Examine the current volume of the *Journal* to see how tables are set up (Appendix C).

Note especially the following concerning *numbered tables*:

Type each table on a separate page, using paper without the lines numbered.

Number the tables with arabic numerals.

Use horizontal lines above and below the headings and below the columns, and seldom elsewhere. Never use vertical lines; leave extra spaces instead.

Indicate table footnotes by superscript small letters and type them below the table.

Place the tables after the list of references.

Where each table is first referred to, type in the margin "Table — near here."

Note that *text tables* are not numbered, they are typed with the text, they seldom need horizontal lines, and the data are arranged in as few rows as possible (Appendix C).

Illustrations

Send the original and two clear copies of each illustration with the manuscript. At the lower left of each figure and copy, give the author's name and the figure number. Also type each caption with its figure for identification. For photographs, type this information on a strip of paper and fasten it to the back of the print. Do not write or type on the print itself. Also, type the captions in succession on a separate page, headed "Captions for illustrations." Put this page at the end of the manuscript.

Where each figure is first referred to, type in the margin "Fig. — near here."

Mathematical Expressions, Equations, and Formulas

Leave three spaces above and below lines that have much material in superscripts or subscripts, and above and below equations and formulas. In the various expressions, place each component in its correct position (Appendix D).

Show all symbols clearly. In the margin, spell out Greek letters the first time they occur, and distinguish between the small letter l and the numeral one, and between the capital letter O and the numeral zero. Make other explanatory notes similarly.

References

Check the text to see that all references in the list are referred to. Type the reference list, double-spaced, in the style that is used in the *Journal* (Appendix E). Names of journals are abbreviated as in the *Biological Abstracts* list, but if an abbreviation is in doubt, type the name in full.

Spellings

A list of about 100 words common in fisheries journals is given in Appendix F.

Appendices

Appendices A to F are available on request from the Office of the Editor.

Journal
Fisheries
Research
Board
Canada

Guide pour les secrétaires d'auteurs

Lisez le "Guide des auteurs" dans l'édition courante du *Journal*. Si vous avez des doutes sur la façon de taper ou d'arranger les détails, suivez la pratique du *Journal*.

Tapez le manuscrit sur un papier blanc et non un papier pelure, mesurant de préférence 8½ × 11 po. (21.5 × 28 cm) et laissant une marge d'au moins 1 po. (2.5 cm). Si possible, employez un papier avec des lignes numérotées dans la marge. Employez un ruban nylon ou carbone et gardez les clés du dactylo nettes.

Chaque partie du manuscrit doit être tapée à double-interligne au moins. La chose est particulièrement importante dans le cas des tableaux, légendes d'illustrations, renvois au bas de la page et listes de références bibliographiques. Evitez de souligner à moins que la matière ne soit en italique. Mettez en retrait la première ligne de chaque paragraphe du texte, ainsi que de chaque légende et renvoi.

Dans les titres et en-têtes, n'employez la majuscule que pour le premier mot, les noms propres et les adjectifs. Pour les petites majuscules, utilisez les petites lettres.

Indiquez tous les renvois au texte par des chiffres arabes en-tête. Numérotez-les consécutivement à travers le texte en commençant par ceux de la page-titre. Placez chaque renvoi immédiatement sous sa référence, le séparant du texte par des lignes horizontales.

La première page ne doit donner que le titre du sujet, le nom et l'affiliation de l'auteur ou des auteurs, et tout autre renvoi utile (Appendice A). Tapez le résumé sur une page séparée (Appendice B). Numérotez chaque page, débutant avec la page-titre.

Voyez à ce que l'auteur vérifie le manuscrit final, et soumettez la première copie et un double du travail au Directeur de la publication.

Tableaux

Consultez une copie du *Journal* pour savoir composer les tableaux et placer les lignes qui y entrent (Appendice C).

Portez une attention particulière à ce qui suit concernant les *tableaux numérotés*.

Tapez les tableaux sur des pages séparées, en utilisant du papier sans lignes numérotées.

Numérotez les tableaux avec des chiffres arabes.

Employez des lignes horizontales au-dessus et au-dessous des en-têtes et au-dessous des colonnes, et très rarement ailleurs. N'employez jamais de lignes verticales; de préférence, laissez de l'espace supplémentaire.

Indiquez les renvois dans les tableaux au moyen de petites lettres italiques en position supérieure et tapez-les au bas de la page.

Placez les tableaux après la liste de références.

A l'endroit où un tableau est mentionné pour la première fois, tapez dans la marge "Tableau (- - -) près d'ici."

Remarquez que les *tableaux dans le texte* ne sont pas numérotés, ils sont tapés avec le texte. Ils ont rarement besoin de lignes horizontales, et l'information est préparée de façons à prendre le moins de rangées possibles.

Illustrations

Joignez au manuscrit expédié le dessin original des illustrations et des photocopies en deux exemplaires.

Au bas et à gauche de chaque figure et photocopie, inscrivez le nom de l'auteur et le numéro de la figure. Aussi, tapez chaque légende avec sa figure pour fin d'identification. Pour les photographies, tapez l'information sur une lisière de papier et collez-la au dos de la photographie. N'écrivez pas et ne tapez pas sur la photographie même. Tapez ensemble sur une feuille séparée et par ordre consécutif les légendes des illustrations, et intercalez cette feuille à la suite du texte.

A l'endroit où chaque figure est mentionnée pour la première fois, tapez dans la marge "Fig. (- - -) près d'ici."

Equations, formules et expressions mathematiques

Laissez trois espaces au-dessus et au-dessous des lignes qui contiennent du matériel en positions supérieures ou en positions inférieures, et au-dessus et au-dessous d'équations et de formules. Dans les différentes expressions, placez chaque composante dans sa position appropriée (Appendice D).

Indiquez les symboles clairement. Dans la marge, épelez les lettres grecques la première fois qu'elles apparaissent et faites une distinction entre la lettre "l" et le chiffre "un" et entre la majuscule "O" et le

chiffre "zéro." Procédez de la même façon pour d'autres notes explicatives.

References

Vérifiez le texte afin d'assurer que sont mentionnées toutes les références ou renvois de la liste. Tapez, à doubles interlignes et de la façon prévue (Appendice E) pour le *Journal*, la liste de références. Les noms de journaux sont abrégés suivant la *Biological Abstracts*, mais s'il y a doute, écrivez le nom au long.

Vocabulaire

Une liste d'environ cent mots relatifs aux articles sur les pêcheries est disponible au bureau du Directeur de la publication (Appendice F).

Appendices

Les appendices de A à F sont disponibles sur demande au bureau du Directeur de la publication.

Announcing

an

International Symposium

St. Andrews N.B.:

The Atlantic Salmon

Management, Biology and Survival of the Species

September 20-22, 1972

Atlantic salmon have been diminishing steadily in many areas where they were formerly abundant; they have disappeared entirely from others. In the absence of an extraordinary cooperative effort to learn how to improve the management of salmon and salmon rivers, and to regulate exploitation, stocks will continue to decline until the Atlantic salmon will have disappeared from most, if not all, of the remaining salmon rivers.

The biology of Atlantic salmon, the problems of river management, factors influencing natural reproduction, exploitation limitations, the economics of Atlantic salmon fisheries, fish farming, hatchery rearing and many other subjects are still not well understood.

The purpose of the Symposium is to seek the best available knowledge on all these subjects; to provide a forum for its presentation and discussion; to use that knowledge as the basis of recommendations for improving Atlantic salmon management programs; and finally to disseminate this new knowledge through publication of the Symposium proceedings so that this knowledge may continue to serve as a guide for enlightened Atlantic salmon management programs.

The Symposium program will be of interest to anyone who cares about the future of this valuable resource.

Attendance at the Symposium is open to anyone.

Offers to present papers on one of the Symposium subjects are welcomed and should be addressed to:

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